PROCEEDINGS

OF THE

TWENTY-THIRD ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

CONGRESS HOTEL, CHICAGO, ILLINOIS

March 14, 15 and 16, 1922

VOLUME 23

PUBLISHED BY

AMERICAN RAILWAY ENGINEERING ASSOCIATION
CHICAGO

1922

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CONSTITUTION

CONSTITUTION.

REVISED AT THE FIFTH, EIGHTH, TWELFTH AND TWENTY-THIRD ANNUAL CONVENTIONS.

ARTICLE I.

Name, Object and Location.

Name.

1. The name of this Association is the American Railway Engineering Association.

Object.

2. Its object is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

Means to Be Used.

3. The means to be used for this purpose shall be as follows:

(a) Meetings for the reading and discussion of reports and papers and for social intercourse.

(b) Investigation of matters pertaining to the objects of the Association through Standing and Special Committees.

(c) The publication of papers, reports and discussions.

(d) The maintenance of a library.

Responsibility.

4. Its action shall be recommendatory, and not binding upon its members.

Location of Office.

5. Its permanent office shall be located in Chicago, Ill., and the annual convention shall be held in that city.

ARTICLE II.

Membership.

Membership Classes.

1. The membership of this Association shall be divided into three classes, viz.: Members, Honorary Members and Associates.

Membership Qualifications.

(2) A Member shall be:

(a) Either a Civil Engineer, a Mechanical Engineer, an Electrical Engineer, or an official of a railway corporation, who has had not less than five (5) years' experience in the location, construction, maintenance or operation of railways, and who, at the time of application for membership, is engaged in railway service in a responsible position in charge of work connected with the Location, Construction, Operation or Maintenance of a Railway; provided, that all persons who were Active Members prior to March 20, 1907, shall remain Members except as modified by Article II, Clause 9.

(b) A Professor of Engineering in a college of recognized standing

Honorary Membership Qualifications.

3. An Honorary Member shall be a person of acknowledged eminence in railway engineering or management. The number of Honorary Members shall be limited to ten.

Associate Membership Qualifications.

4. An Associate shall be a person not eligible as a Member, but whose pursuits, scientific acquirements or practical experience qualify him to co-operate with Members in the advancement of professional knowledge, such as Consulting, Inspecting, Contracting, Government or other Engineers, Instructors of Engineering in Colleges of recognized standing, and Engineers of Industrial Corporations when their duties are purely technical.

Membership Rights.

5. (a) Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights of Members, except that of holding office, and shall be exempt from the payment of dues.

(c) Associates shall have all the rights of Members, except those of voting and holding office.

Age Requirement.

6. An applicant to be eligible for membership in any class shall not be less than twenty-five (25) years of age.

"Railway" Defined.

7. The word "railway" in this Constitution means one operated by steam or electricity as a common carrier, dependent upon transportation for its revenue. Engineers of street railway systems and of railways which are used primarily to transport the material or product of an industry or industries to and from a point on a railway which is a common carrier, or those which are merely adjuncts to such industries, are eligible only as Associates.

Changes in Classes.

8. A Member, elected after March 20, 1907, who shall leave the railway service, shall cease to be a Member, but may retain membership in the Association as an Associate, subject to the provisions of Article II, Clause 9; provided, however, if he re-enters the railway service, he shall be restored to the class of Members.

Supply Men.

9. Persons whose principal duties require them to be engaged in the sale or promotion of railway patents, appliances or supplies, shall not be eligible for, nor retain membership in any class in this Association, except that those who were Active Members prior to March 20, 1907, may retain membership as Associates; provided, however, that anyone having held membership in the Association and subsequently having become subject to the operation of this clause, shall, if he again becomes eligible, be permitted to re-enter the Association, without the payment of a second entrance fee.

Transfers.

10. The Board of Direction shall transfer members from one class to another, or remove a member from the membership list, under the provisions of this Article.

ARTICLE III.

Admissions and Expulsions.

Charter Membership.

1. The Charter Membership consists of all persons who were elected before March 15, 1900.

Application for Membership.

2. The Charter Membership having been completed, any person desirous of becoming a member shall make application upon the form prescribed by the Board of Direction, setting forth in a concise statement his name, age, residence, technical education and practical experience He shall refer to at least three members to whom he is personally known, each of whom shall be requested by the Secretary to certify to a personal knowledge of the candidate and his fitness for membership.

Election to Membership.

3. Upon receipt of an application properly endorsed, the Board of Direction, through its Secretary, or a Membership Committee selected from its own members, shall make such investigation of the candidate's

fitness as may be deemed necessary. The Secretary will furnish copies of the information obtained and of the application to each member of the Board of Direction. At any time, not less than thirty days after the filing of the application, the admission of the applicants shall be canvassed by letter-ballot among the members of the Board, and affirmative votes by two-thirds of its members shall elect the candidate; provided, however, that should an applicant for membership be personally unknown to three members of the Association, due to residence in a foreign country, or in such a portion of the United States as precludes him from a sufficient acquaintance with its members, he may refer to well-known men engaged in railway or allied professional work, upon the form above described, and such application shall be considered by the Board of Direction in the manner above set forth, and the applicant may be elected to membership by a unanimous vote of the Board.

Subscription to Constitution.

4. All persons, after due notice from the Secretary of their election, shall subscribe to the Constitution on the form prescribed by the Board of Direction. If this provision be not complied with within six months of said notice, the election shall be considered null and void.

Reinstatement.

5. Any person having been a member of this Association, and having, while in good standing, resigned such membership, may be reinstated without the payment of a second entrance fee; provided his application for reinstatement is signed by five members certifying to his fitness for same, and such application is passed by a two-thirds majority of the Board of Direction.

Honorary Membership.

6. Proposals for Honorary Membership shall be submitted by ten or more Members. Each member of the Board of Direction shall be furnished with a copy of the proposal, and if, after thirty days, the nominee shall receive the unanimous vote of said Board, he shall be declared an Honorary Member.

Expulsions.

7. When charges are preferred against a Member in writing by ten or more Members, the Member complained of shall be served with a copy of such charges, and he shall be called upon to show cause to the Board of Direction why he should not be expelled from the Association. Not less than thirty days thereafter a vote shall be taken on his expulsion. and he shall be expelled upon a two-thirds vote of the Board of Direction.

Resignations.

8. The Board of Direction shall accept the resignation, tendered in writing, of any Member whose dues are fully paid up.

ARTICLE IV.

Dues.

Entrance Fee.

1. An entrance fee of $10.00 shall be payable to the Association through its Secretary with each application for membership; and this sum shall be returned to the applicant if not elected.

Annual Dues.

2. *The annual dues are $10.00, payable during the first three months of the calendar year.

Arrears.

3. Any person whose dues are not paid before April 1st of the current year shall be notified of same by the Secretary. Should the dues not be paid prior to July 1st, the delinquent Member shall lose his right to vote. Should the dues remain unpaid October 1st, he shall be notified on the form prescribed by the Board of Direction, and he shall no longer receive the publications of the Association. If the dues are not paid by December 31st, he shall forfeit his membership without further action or notice, except as provided for in Clause 4 of this Article.

Remission of Dues.

4. The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member who, from ill-health, advanced age or other good reasons, is unable to pay them.

ARTICLE V.

Board of Direction.

Officers.

1. The officers of the Association shall be Members and shall consist of:

A President,
A First Vice-President,
A Second Vice-President,
A Secretary,
A Treasurer,
Nine Directors,

*The annual payment of $10.00 made by each member is to be subdivided and credited on the books of the Association, as follows: To member's subscription to the Bulletin, $5.00: annual dues, $5.00.

who, together with the five latest living Past-Presidents who are Members, shall constitute the Board of Direction in which the government of the Association shall be vested, and who shall act as Trustees, and have the custody of all property belonging to the Association.

Vice-Presidents' Priority.

2. The offices of First and Second Vice-Presidents shall be determined by the priority of their respective dates of election.

Terms of Office.

3. The terms of office of the several officers shall be as follows:

President, one year.
Vice-Presidents, two years.
Secretary, one year.
Treasurer, one year.
Directors, three years.

Officers Elected Annually.

4. (a) There shall be elected at each Annual Convention:

A President,
One Vice-President,
A Secretary,
A Treasurer,
Three Directors.

(b) The candidates for President and for Vice-President shall be selected from the past or present members of the Board of Direction.

Conditions of Re-election of Officers.

5. The office of President shall not be held twice by the same person. A person who shall have held the office of Vice-President or Director shall not be eligible for re-election to the same office until at least one full term shall have elapsed after the expiration of his previous term of office.

Term of Officers.

6. The term of each officer shall begin with his election and continue until his successor is elected.

Vacancies in Offices.

7. (a) A vacancy in the office of President shall be filled by the First Vice-President.

(b) A vacancy in the office of either of the Vice-Presidents shall be filled by the Board of Direction by election from the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) Any other vacancies for the unexpired term in the membership of the Board of Direction shall be filled by the Board.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office he is holding; provided, however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provision of Article V, Clause 5.

Vacation of Office.

8. When an officer ceases to be a Member of the Association, as provided in Article II, his office shall be vacated, and be filled as provided in Article V, Clause 7.

Disability or Neglect.

9. In case of the disability or neglect in the performance of his duty, of an officer, the Board of Direction, by a two-thirds majority vote of the entire Board, shall have power to declare the office vacant, and fill it as provided in Article V, Clause 7.

ARTICLE VI.

Nomination and Election of Officers.

Nominating Committee.

1. (a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members and five Members not officers.

(b) The five Members shall be elected annually when the officers of the Association are elected.

Number of Candidates.

2. It shall be the duty of this Committee to nominate candidates to fill the offices named in Article V, and vacancies in the Nominating Committee caused by expiration of term of service, for the ensuing year, as follows:

Office to be Filled.	Number of Candidates to be named by Nominating Committee.	Number of Candidates to be Elected At Annual Election of Officers.
President	1	1
Vice-President	2	1
Secretary	1	1
Treasurer	1	1
Directors	9	3
Nominating Committee	10	5

Chairman.

3. The Senior Past-President shall act as permanent chairman of the Committee, and will issue the call for meetings. In his absence from meetings, the Past-President next in age of service shall act as Chairman pro tem. at the meeting.

Meeting of Committee.

4. Prior to December 1st each year, the Chairman shall call a meeting of the Committee at a convenient place and, at this meeting, nominees for office shall be agreed upon.

Announcement of Names of Nominees.

5. The names of the nominees shall be announced by the permanent Chairman to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

Additional Nominations by Members.

6. At any time between January 1st and February 1st, any ten or more Members may send to the Secretary additional nominations for the ensuing year signed by such Members.

Vacancies in List of Nominees.

7. If any person so nominated shall be found by the Board of Direction to be ineligible for the office for which he is nominated, or should a nominee decline such nomination, his name shall be removed and the Board may substitute another one therefor; and may also fill any vacancies that may occur in this list of nominees up to the time the ballots are sent out.

Ballots Issued.

8. Not less than thirty days prior to each Annual Convention, the Secretary shall issue ballots to each voting member of record in good standing, with a list of the several candidates to be voted upon, with the names arranged in alphabetical order when there is more than one name for any office.

Substitution of Names.

9. Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

Ballots.

10. (a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw his ballot, and may substitute another, at any time before the polls close.

Invalid Ballots.

11. Ballots not endorsed or from persons not qualified to vote shall not be opened; and any others not complying with the above provisions shall not be counted.

Closure of Polls.

12. The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by three tellers appointed by the Presiding Officer. The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

Requirements for Election.

13. The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

Tie Vote.

14. In case of a tie between two or more candidates for the same office, the members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

Announcement.

15. The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

First Nominating Committee.

16. Except as to the Past-Presidents, the first Nominating Committee and the three additional Directors provided for shall be appointed by the Board of Direction, one of the Directors for one year, one for two years and one for three years.

ARTICLE VII.

Management.

Duties of President.

1. (a) The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio member of all Committees, except the Nominating Committee.

(b) The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and discharge his duties in case of a vacancy in his office.

Duties of Secretary.

2. The Secretary shall be, under the direction of the President and Board of Direction, the Executive Officer of the Association. He shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. He shall see that the moneys due the Association are collected and without loss transferred to the custody of the Treasurer. He shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. He is to conduct the correspondence of the Association and keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

Duties of Treasurer.

3. The Treasurer shall receive all moneys and deposit same in the name of the Association, and shall receipt to the Secretary therefor. He shall invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. He shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

Auditing of Accounts.

4. The accounts of the Treasurer and Secretary shall be audited annually by a public accountant, under the direction of the Finance Committee of the Board.

Duties of Board.

5. The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

Board Meetings.

6. The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct Special meetings shall be called on request, in writing, of five members of the Board.

Board Quorum.

7. Seven members of the Board shall constitute a quorum.

Board Committees.

8. At the first meeting of the Board after the Annual Convention, the following committees from its members shall be appointed by the

President, and shall report to and perform their duties under the supervision of the Board of Direction:

a. Finance Committee of three members.
b. Publication Committee of three members.
c. Library Committee of three members.
d. Outline of work of Standing Committees of five members.

Duties of Finance Committee.

9. The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of moneys and as to other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by previous action and authority of the Board of Direction.

Duties of Publication Committee.

10. The Publication Committee shall have general supervision of the publications of the Association.

Duties of Library Committee.

11. The Library Committee shall have general supervision of the Library, the property therein, and the quarters occupied by the Secretary; shall make recommendations to the Board with reference thereto, and shall direct the expenditure for books and other articles of permanent value, from such sums as may be appropriated for these purposes.

Duties of Committee on Outline of Work of Standing Committees.

12. The Committee on Outline of Work of Standing Committees shall present a list of subjects for committee work during the ensuing year at the first meeting of the Board of Direction after the Annual Convention.

Standing Committees.

13. The Board of Direction may appoint such Standing Committees as it may deem best, to investigate, consider and report upon questions pertaining to railway location, construction or maintenance.

Special Committees.

14. Special Committees to examine into and report upon any subject connected with the objects of this Association may be appointed from time to time by the Board of Direction.

Discussion by Non-Members.

15. The Board of Direction may invite discussions of reports from persons not members of the Association.

Sanction of Acts of Board.

16. An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next Annual Convention of the Association shall be deemed to be the act of the Association, and shall not afterwards be impeached by any Member.

ARTICLE VIII.

Meetings.

Annual Convention.

1. The Annual Convention shall begin upon the third Tuesday in March of each year, and shall be held at such place in the City of Chicago as the Board of Direction may select.

Special Meetings.

2. Special meetings of the Association may be called by the Board of Direction, and special meetings shall be so called by the Board upon request of thirty Members, which request shall state the purpose of such meeting. The call for such meeting shall be issued not less than ten days in advance, and shall state the purpose and place thereof, and no other business shall be taken up at such meeting.

Notification of Annual Convention.

3. The Secretary shall notify all members of the time and place of the Annual Convention of the Association at least thirty days in advance thereof.

Association Quorum.

4. Twenty-five Members shall constitute a quorum at all meetings of the Association.

Order of Business.

5. (a) The order of business at annual conventions of the Association shall be as follows:

Reading of minutes of last meeting.
Address of the President.
Reports of the Secretary and Treasurer.
Reports of Standing Committees.
Reports of Special Committees.
Unfinished business.

New business.
Election of officers.
Adjournment.

(b) This order of business, however, may be changed by a majority vote of members present.

Rules of Order.

6. The proceedings shall be governed by "Robert's Rules of Order," except as otherwise herein provided.

Discussion.

7. Discussion shall be limited to members and to those invited by the presiding officer to speak.

ARTICLE IX.

Amendments.

Amendments.

1. Proposed amendments to this Constitution shall be made in writing and signed by not less than ten Members, and shall be acted upon in the following manner:

The amendments shall be presented to the Secretary, who shall send a copy of same to each member of the Board of Direction as soon as received. If at the next meeting of the Board of Direction a majority of the entire Board are in favor of considering the proposed amendments, the matter shall then be submitted to the Association for letter-ballot, and the result announced by the Secretary at the next Annual Convention. In case two-thirds of the votes received are affirmative, the amendments shall be declared adopted and become immediately effective

GENERAL INFORMATION.

(Subject to change from time to time by Board of Direction.)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS.

(A) Appointment of Committees and Outline of Work.

Standing Committees.

1. The following are Standing Committees:

I. Roadway.
II. Ballast.
III. Ties.
IV. Rail.
V. Track.
VI. Buildings.
VII. Wooden Bridges and Trestles.
VIII. Masonry.
IX. Signs, Fences and Crossings.
X. Signals and Interlocking.
XI. Records and Accounts.
XII. Rules and Organization.
XIII. Water Service.
XIV. Yards and Terminals.
XV. Iron and Steel Structures.
XVI. Economics of Railway Location.
XVII. Wood Preservation.
XVIII. Electricity.
XIX. Conservation of Natural Resources. (Abolished.)
XX. Uniform General Contract Forms.
XXI. Economics of Railway Operation.
XXII. Economics of Railway Labor.
XXIII. Shops and Locomotive Terminals.

Special Committees.

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Clause 14, of the Constitution.

The following are Special Committees:

Stresses in Railroad Track.
Standardization.
Clearance Diagram.

Personnel of Committees.

3. The personnel of all Committees will continue from year to year, except when changes are announced by the Board of Direction. Ten per cent. of the membership of each Committee shall be changed each year.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding Annual Convention.

Outline of Work.

4. As soon as practicable after each Annual Convention the Board of Direction will assign to each Committee the important questions which, in its judgment, should preferably be considered during the current year. Committees are privileged to present the results of any special study or investigation they may be engaged upon or that may be considered of sufficient importance to warrant presentation.

(B) Preparation of Committee Reports.

General.

5. The collection and compilation of data and subsequent analysis in the form of arguments and criticism is a necessary and valuable preliminary element of committee-work.

Collection of Data.

6. Committees are privileged to obtain data or information in any proper way. The Secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

Plan of Reports.

7. Committee reports should be prepared as far as practicable to conform to the following general plan:

(a) It is extremely important that every Committee should examine its own subject-matter in the "Manual" prior to each Annual Convention, and revise and supplement it, if deemed desirable, giving the necessary notice of any recommended changes in accordance with Clause 6 (a) of the General Rules for the Publication of the "Manual." If no changes are recommended, statement should be made accordingly.

(b) When deemed necessary, the previous report should be reviewed

(c) Subjects presented in previous reports on which no action was taken should be resubmitted, stating concisely the action desired. It may not be necessary to repeat the original text in the report, reference to former publication being sufficient, unless changes in the previously published version are extensive. Minor changes can be explained in the text of the report.

Definitions.

(d) Technical terms used in the report, the meaning of which is not clearly established, should be defined, but defined only from the standpoint of railway engineering.

History.

(e) If necessary, a brief history of the subject-matter under discussion, with an outline of its origin and development, should be given.

Analysis.

(f) An analysis of the most important elements of the subject-matter should be given.

Argument.

(g) The advantages and disadvantages of the present and recommended practices should be set forth.

Illustrations.

(h) Illustrations accompanying reports should be prepared so that they can be reproduced on one page. The use of folders should be avoided as much as possible, on account of the increased expense and inconvenience in referring to them. Plans showing current practice, or necessary for illustration, are admissible, but those showing proposed definite design or practice should be excluded. Recommendations should be confined to governing principles.

Illustrations should be made on tracing cloth with heavy black lines and figures, so as to stand a two-thirds reduction; for example: To come within a type page (4 inches by 7 inches), the illustration should be made three times the above size.

To insure uniformity, the one-stroke, inclined Gothic lettering is recommended.

Photographs should be clear and distinct silver prints.

Conclusions.

(i) The conclusions of the Committee which are recommended for publication in the Manual should be stated in concise language, logical sequence, and grouped together, setting forth the principles, specifications, definitions, forms, tables and formulas included in the recommendation. Portions of the text of the report which are essential to a clear interpretation and understanding of the conclusions, should be included as an integral part thereof.

(C) Publication of Committee Reports.

Reports Required.

8. (a) Reports will be required from each of the Standing and Special Committees each year.

(b) Although several subjects may be assigned to each Committee by the Board of Direction, a full report on only one subject is expected at each Annual Convention, but the preliminary work on some of the remaining subjects should be in progress, and, when deemed advisable, partial reports of progress should also be presented. This method allows time for their proper preparation and consideration.

Date of Filing Reports.

9. Committee reports to come before the succeeding convention for discussion should be filed with the Secretary not later than November 30th of each year.

10. Committees engaged upon subjects involving an extended investigation and study are privileged to present progress reports, giving a brief statement of the work accomplished, and, if deemed expedient, a forecast of the final report to be presented.

Publication of Reports.

11. Committee reports will be published in the Bulletin in such sequence as the Board of Direction may determine, for consideration at the succeeding convention. Reports will be published in the form presented by the respective Committees. Alterations ordered by the convention will be printed as an appendix to the report.

Written Discussions.

12. Committees should endeavor to secure written discussions of published reports. Written discussions will be transmitted to the respective Committees, and if deemed desirable by the Committee, the discussions will be published prior to the convention and be considered in connection with the report.

Verbal Discussions.

13. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

Sequence.

(D) Consideration of Committee Reports.

14. The sequence in which Committee reports will be considered by the convention will be determined by the Board of Direction.

Method.

15. The method of consideration of Committee reports will be one of the following:

(a) Reading by title.

(b) Reading, discussing and acting upon each conclusion separately.

(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Final Action.

16. Action by the convention on Committee reports will be one of the following, after discussion is closed:

(a) Receiving as information.

(b) Receiving as a progress report.

(c) Adoption of a part complete in itself and referring remainder back to Committee.

(d) Adoption as a whole.

(e) Recommittal with or without instructions.

(f) Adoption as a whole.

(g) Recommendation to publish in the Manual.

Note.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the Committee considers affected.

The Chair will decline to entertain amendments which in his opinion lie entirely within the duties of the Editor.

(E) Publication by Technical Journals.

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the Bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or Committees presenting such material.

BUSINESS SESSION

PROCEEDINGS

The object of this Association is the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways. Its action is not binding upon its Members.

TUESDAY, MARCH 14, 1922

MORNING SESSION

The Twenty-third Annual Convention of the American Railway Engineering Association was called to order by the President, Mr. L. A. Downs, Vice-President and General Manager, Central of Georgia Railway, at 9:45 a. m.

The President:—Gentlemen, the Twenty-third convention of the American Railway Engineering Association is now in session ready for business. The members will please come to order.

The first order of business is the reading of the Minutes of the last meeting, but inasmuch as these are very voluminous, we will dispense with reading them, unless there is some objection.

ADDRESS OF PRESIDENT L. A. DOWNS

We are just about ready to pass the twenty-third milestone in the existence of the American Railway Engineering Association, and I am pleased and happy to advise you that we did not move backward during the past year. Our financial condition is good, notwithstanding the fact that nearly all other associations, clubs and organizations of like character during these bad times have had to make assessments and many of these organizations, notwithstanding these assessments, have had deficits, but I am pleased to advise you that we made all of our expenses and nearly $1,800 in addition, so that our financial affairs are in very good shape.

Our membership has increased. We received 129 new members into this Association during the past year. This is on top of the big drive for membership made in the previous year when there were nearly 600 new members admitted, and we think that the record for last year is very gratifying. The average increase of membership in the Association is 125 yearly, and to get 129 during the past year has put us certainly on the right track and shows what we are doing in the way of increased membership.

We now have a total of 1,960 members in the Association. We dropped an unusually large number of members the past year, 115 on account of non-payment of dues, the largest number we have ever dropped, but the house was cleaned this year and we have now a good going organization.

There were 16 deaths during the past year among the members of our Association, one being Col. Webb, of the Board of Direction, and another, our first President, Mr. J. F. Wallace.

We have continued our affiliations with the American Railway Association in a very creditable manner, and I take pleasure in announcing to you that this convention is also a meeting of the Engineering Division of the American Railway Association, and our reports go to the American Railway Association for endorsement.

During the past year we have been admitted to membership in the American Engineering Standards Committee. This action has been approved by the American Railway Association and they have given authority to the Association to have Mr. Frink act as our representative on the American Engineering Standards Committee.

We have co-operated with other organizations during the past year, especially with the Joint Committee on Concrete and Reinforced Concrete, the American Society of Civil Engineers, and the American Society for Testing Materials, and others.

We have continued our contact, or rather tried to, with the universities. Dean Potter of Purdue University has invited the committee from this Association to visit Purdue. Two dates were set for a meeting of this committee, but through some unaccountable reason each date had to be postponed. It is hoped that this meeting will be held in the near future.

The Association has authorized the appointment of a committee to work out a means whereby a better contact with universities could be made. We are very mindful that such a thing is necessary. We have thought the matter over during the past year, it having been brought up in a part of the Presidential address of the last annual convention, that we should make this our duty to bring about these closer relations, but so far, I regret to say, nothing has been done. We expect, however, something constructive to be accomplished during this coming year and we hope that something will be done. We need the universities and the universities need us, and closer contact is necessary.

I sent a questionnaire to 19 universities a short time ago—19 representative technical schools of the United States—to which I received 15 replies. Out of these 15 replies there were 12 that gave definite information as to their graduates. During the past 10 years, from 1911 to 1921, there were 3,003 graduates in civil engineering, and, surprising as it may seem, only 272 or 9 per cent are working for railroads. I did not find out how many of the men in the engineering departments of the railroads were graduates of engineering schools, but in the case of two railroads, where I had a count made, that employed about 350 engineers, only about 50 per cent are graduates of technical schools. Therefore, something must be done to bring technical men into railroad work.

In the southeast, I made a canvass to discover what are the wages paid to the young engineering graduates who desire to enter railroad work in the Engineering Department, and I found that the average salary is $118 monthly. I am not in sympathy with the so-called welfare work of another engineering society in its uplifting of wages, but I want to say that if the managers of the railroads of the United States want the services of trained men they must fix some attractive wage for college graduates to start on. When we pay a fireman $175 a month to start, a flagman $141, a switchman $181, and a car repairer $143, and a graduate of a technical engineering school $118, there is something wrong with the principles of the wages paid on railroads. (Applause.)

The real test of the good work the Association is doing is whether our recommendations are being put into practice on the railways. The executive head of every railway having members in the Association or not, should put it up to the head of the Engineering Department as to whether the recommendations of the American Railway Engineering Association are being made use of in that Department, and if not, to give reasons for not doing so. The answers to that question will be constructive criticism, and our Association will know its destiny from such reports. I thank you. (Applause.)

The next order of business is the reports of the Secretary and of the Treasurer.

Secretary E. H. Fritch presented the following reports of the Secretary and of the Treasurer:

REPORT OF THE SECRETARY

March 1, 1922

To the Members:

Report on the general affairs of the Association for the past year is respectfully submitted.

Finances

Exhibit A, appended hereto, gives a detailed record of the receipts and expenditures, from which the following items are abstracted:

Receipts	$48,111.75
Expenditures	46,358.46
Excess of Receipts over Expenditures	$ 1,753.29
Total Cash Assets	$44,742.51

Membership

The following is a report on the present membership of the Association:

Membership March 1, 1921			1,951
Deceased members	16		
Resignations and dropped	115		
		—131	
Additions during the year		143	
Gain			12
Tothal membership March 1, 1922			1,960

A

Deceased Members

The losses sustained by death during the year were:

F. E. Bissell, Consulting Engineer
J. S. Browne, Assistant to Engineer Maintenance of Way, New York, New Haven and Hartford Railroad
F. F. Busteed, ex-General Superintendent, Canadian Pacific Railway
H. C. Ferris, Receiver, Muskogee, Oklahoma and Gulf Railway
F. W. Leatherbury, Division Engineer, Gulf, Colorado and Santa Fe Railway
W. H. Given, Operating Department, Rock Island Lines
J. F. Keegan, General Superintendent, Baltimore and Ohio Railroad
G. C. Millet, Assistant to Chief Engineer, Atchison, Topeka and Santa Fe Railway, Coast Lines
Major John W. Moore, Assistant Engineer, Illinois Central Railroad
R. J. Parker, General Manager, Atchison, Topeka and Santa Fe Railway Western Lines
R. M. Pearce, Resident Engineer, Pittsburgh and Lake Erie Railroad
C. W. Pifer, Office Engineer, U. S. Railroad Administration
J. R. Savage, General Superintendent, Long Island Railroad
Colonel George D. Snyder, Consulting Engineer
John Findley Wallace (Past-President), Chairman, Chicago Railway Terminal Commission
Colonel George H. Webb (Director), Chief Engineer, Michigan Central Railroad.

Committee Reports

The results of the labors of the Standing and Special Committees during the year are embodied in the printed reports presented to you for consideration at this meeting.

The committees have rendered the Association and to the railways a valuable service, and are to be commended for their good work.

Revised Manual

Further time is requested in which to complete work on the revised Manual. Five hundred pages of the volume are already printed. It is now expected to have the Manual ready for distribution about July 1st.

Approval of Recommendations by American Railway Association

The recommendations adopted at the March, 1921, annual meeting of the American Railway Engineering Association—functioning also as the Engineering Division of the American Railway Association—were presented to the November, 1921, session of the latter organization for endorsement.

The subjects receiving such endorsement by the American Railway Association are as follows:

(a) Subsidence and shrinkage of embankments;
(b) Drainage of large cuts;
(c) Instructions to govern ballasting on an operated line;

(d) Specifications for stone ballast material;
(e) Specifications for washed gravel;
(f) Standard ballast tools;
(g) Specifications for cross-ties and for switch-ties;
(h) Rail record forms;
(i) Specifications for switches, frogs, crossings and guard-rails;
(j) Specifications, classification and grading rules for lumber and timber used in the Maintenance of Way Department;
(k) Roadway information signs;
(l) Manual of instructions for the guidance of engineering field parties;
(m) Manual of instructions for the guidance of employees of the Maintenance of Way Department;
(n) Science of organization;
(o) Specifications and plans for railway water tanks;
(p) Methods of economic transfer of lading of bad-order cars by mechanical means or otherwise;
(q) Rules and unit stresses for rating existing bridges;
(r) Principles and detailed design of flashing, drainage, reinforcement and protection of railroad bridges for waterproofing purposes;
(s) Form of lease agreement for industrial site.

Standardization

The American Railway Association has taken out membership in American Engineering Standards Committee, and designated a member of the Engineering Division to be its official representative on that body. Mr. E. A. Frink, Chairman of the Standardization Committee of your Association, has been appointed to act in that capacity, with Mr. J. R. W. Ambrose as alternate.

Among the matters now pending before the A. E. S. C., with the view of standardization, in which your Association is concerned, are the following:

Railroad Cross-Ties and Switch-Ties
Pipe Flanges and Fittings
Steel Railway Bridge Specifications
Grading of Lumber
Testing of Wood
Steel Forgings
Bolt, Nut, and Rivet Proportions
Steel Shapes
Insulated Wires and Cables
Overhead Crossing Specifications
Electrical Symbols
Electrical Power Control
Aluminum for Conducting Purposes.

Co-operation with Other Organizations

Your Association has co-operated with other associations on subjects of mutual interest, with beneficial results.

Among the organizations with which conferences have been held during the year are the following:

American Committee on Electrolysis
American Concrete Pipe Association
American Society for Testing Materials
American Society of Civil Engineers
Joint Committee on Concrete and Reinforced Concrete
Manganese Track Society
U. S. Bureau of Surveys and Maps
U. S. Forest Service.
Associated General Contractors of America.

Amendments to Constitution

Two amendments to the Constitution were submitted to vote by letter-ballot during the year: (1) To amend Article V, Section 4, paragraph b, and (2) to amend Article VI, Section 2—the first amendment contemplating the inclusion of *past or* present members of the Board of Direction for eligible candidates for President and for Vice-President; and the second amendment requiring the Nominating Committee to select *two* candidates for Vice-President instead of one candidate.

Both amendments having received a majority number of those voting, the two amendments become effective immediately.

The vote on the two amendments is as follows:

For Amendment No. 1	658
Against Amendment No. 1	58
For Amendment No. 2	685
Against Amendment No. 2	31

Respectfully submitted,

E. H. FRITCH,

Secretary.

Exhibit A

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1921

Balance on hand January 1, 1921		$42,989.22

RECEIPTS

Membership Account		
Entrance Fees	$ 1,970.00	
Dues	11,152.15	
Subscriptions to Bulletin	11,152.15	
Binding Proceedings and Manual	1,652.05	
Badges	15.00	
Sale of Publications		
Proceedings	4,406.11	
Bulletins	1,242.22	
Manual	32.80	
Specifications	539.35	
Leaflets	28.75	
General Index	4.50	
Advertising		
Publications	2,192.30	
Interest Account		
Investments	2,022.50	
Bank Balance	65.86	
Annual Meeting		
Sale of Dinner Tickets	1,212.00	
Miscellaneous	274.52	
American Railway Association		
Rail Committee	10,149.49	
Total	$48,111.75	

DISBURSEMENTS

Salaries	$ 6,800.00	
Proceedings	9,566.26	
Bulletins	12,649.11	
Manual	76.05	
Stationery and Printing	670.18	
Rents, Light, etc.	845.00	
Telegrams and Telephone	37.83	
Supplies	188.36	
Expressage	875.96	
Postage	1,016.39	
Exchange	99.86	
Committee Expenses	77.18	
Officers' Expenses	22.27	
Annual Meeting Expenses	2,271.37	
Refunds Account Duplicate Payments	14.60	
Audit	150.00	
Reprints of Report Joint Committee on Concrete and Reinforced Concrete	325.00	
Rail Committee	10,308.20	
Miscellaneous	364.84	
Total	$46,358.46	
Excess of Receipts over Disbursements		$ 1,753.29
Balance on hand December 31, 1921		$44,742.51
Consisting of:		
Bonds	$40,565.65	
Cash in S. T. & S. Bank	4,151.86	
Petty Cash Fund	25.00	
	$44,742.51	

STRESSES IN TRACK FUND

Balance on hand January 1, 1921		$ 954.85
Received from interest during 1921		26.47
		$ 981.32
Disbursements:		
Transportation	$ 9.84	
Hotels and Meals	7.30	
Supplies	1.98	$ 19.12
Balance on hand in S. T. & S. Bank, December 31, 1921		$ 962.20

Respectfully submitted,

Board of Direction.

REPORT OF THE TREASURER

Balance on hand January 1, 1921		$42,989.22
Receipts during 1921	$48,111.75	
Paid out on audited vouchers, 1921	46,358.46	
Excess of Receipts over Disbursements		$ 1,753.29
Balance on hand December 31, 1921		$44,742.51
Consisting of:		
Bonds	$40,565.65	
Cash in S. T. & S. Bank	4,151.86	
Petty Cash Fund	25.00	
	$44,742.51	

STRESSES IN TRACK FUND

Balance on hand January 1, 1921	$ 954.85
Received from interest during 1921	26.47
Total	$ 981.32
Paid out on audited vouchers, 1921	19.12
Balance on hand December 31, 1921	$ 962.20

The securities listed above are in a safety deposit box of the Merchants' Loan & Trust Safe Deposit Company, Chicago.

Respectfully submitted,

Geo. H. Bremner,
Treasurer.

I have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1921, and find them in accordance with the foregoing financial statements.

Charles Campbell,
Auditor.

GENERAL BALANCE SHEET

December 31, 1921

ASSETS

	1921	1920
Due from Members	$ 1,710.84	$ 3,865.85
Due from Sale of Publications	1,286.82	542.67
Due from Advertising	680.00	495.00
Due from American Railway Association	2,459.68	2,300.12
Due from American Railway Express Co., Claim	....	250.00
Furniture and fixtures (cost)	997.40	997.40
Gold Badges	84.00	49.00
Publications on hand (estimated)	6,000.00	6,000.00
Extensometers	500.00	500.00
Investments (cost)	40,565.65	40,565.65
Interest on Investments (accrued)	750.05	896.84
Cash in Standard Trust & Savings Bank	4,151.86	1,752.97
Cash in Secretary's Office	....	645.60
Petty Cash Fund	25.00	25.00
Total	$62,211.30	$58,886.09

LIABILITIES

	1921	1920
Members Dues paid in advance	$ 5,211.50	$ 1,539.45
Impact Test Fund on Electrified Railways	285.46	285.46
Advertising paid in advance	85.00	60.00
Due for Printing	102.58	7,679.52
Due for Expressage	....	270.89
Surplus	56,526.76	49,050.77
Total	$62,211 30	$58,886.09

On motion of Mr. J. R. W. Ambrose, the reports of the Secretary and of the Treasurer were approved.

The President:—The reports are approved. The Chair extends the privileges of the floor to railroad officials who are not members of this Association, and also to college professors that are present.

The next order of business is the consideration of reports of standing and special committees. The first committee report to be considered is that of the Yards and Terminals Committee. Will the Committee please come forward?

We will have a variation in the reports from former years. The chairman will present the report as a whole, and the vice-chairmen will present the portions for which they are responsible.

The Chairman, Mr. Arthur Montzheimer, Chief Engineer of the Elgin, Joliet & Eastern Railway, will present the report of this Committee.

(For report, see pp. 65-84.)

The President:—The report on Economics of Railway Labor will be presented by the Chairman, Mr. C. E. Johnston, General Manager, Kansas City Southern Railway.

(For report, see pp. 669-705.)

The President:—The report of the Ballast Committee will be submitted by the Chairman, Mr. F. J. Stimson, Chief Engineer Maintenance, Southwest Region, Pennsylvania System.

(For report, see pp. 130-158.)

AFTERNOON SESSION

The President:—The Chair would ask unanimous consent to make a change in the order of the program. The Memorial Meeting to John Findley Wallace and Col. George H. Webb was scheduled for Thursday afternoon, but we would like to hold it on Wednesday morning at 11 o'clock instead. If there is no objection, the change will be made in the program.

The President:—The report of the Committee on Iron and Steel Structures will be presented by the Chairman, Mr. O. E. Selby, Principal Assistant Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway.

(For report, see pp. 159-223.)

The President:—The report of the Standardization Committee will be presented by the Chairman, Mr. E. A. Frink, Principal Assistant Engineer, Seaboard Air Line Railway.

(For report, see pp. 225-228.)

The President:—The report of the Committee on Signals and Interlocking will be presented by the Chairman, Mr. W. J. Eck, Signal and Electrical Superintendent, Southern Railway.

(For report, see pp. 229-231.)

The President:—The report of the Tie Committee will be presented by the Chairman of the Committee, Mr. W. A. Clark, Chief Engineer, Duluth & Iron Range Railroad.

(For report, see pp. 233-262.)

The President:—The report of the Special Committee on Stresses in Railroad Track will be presented by the Chairman of the Committee, Professor A. N. Talbot, of the University of Illinois.

(For report, see p. 429.)

WEDNESDAY, MARCH 15, 1922

MORNING SESSION

The President:—The report of the Committee on Track will be presented by the Chairman, Mr. W. P. Wiltsee, Assistant Engineer, Norfolk & Western Railway.

(For report, see pp. 575-620.)

The President:—The report of the Committee on Shops and Locomotive Terminals will be presented by the Chairman, Mr. F. E. Morrow, Assistant Chief Engineer, Chicago & Western Indiana Railway.

(For report, see pp. 263-391.)

The President:—We will now hold the Memorial Meeting for the late John Findley Wallace and Colonel George H. Webb.

The President:—The Chair will announce the following appointees for Tellers for the election of officers. They are asked to meet with the Secretary immediately after the close of this session: P. H. Winchester, J. K. Pettus, J. V. Johnston, W. Forrest Ogle, O. C. Badger and H. C. Smith.

AFTERNOON SESSION

The President:—The report of the Roadway Committee will be presented by the Chairman, Mr. J. R. W. Ambrose, Chief Engineer, Toronto Terminals Railway.

(For report, see pp. 393-425.)

The President:—The report of the Committee on Economics of Railway Location will be presented by the Chairman, Mr. A. S. Going, Engineer Construction, Grand Trunk Railway.

(For report, see pp. 427-428.)

The President:—The report of the Committee on Electricity will be presented by the Chairman, Mr. Edwin B. Katte, Chief Engineer, Electric Traction, New York Central Railroad.

(For report, see pp. 85-129; also Report on Electrolysis, Part II, pp. 1-176.)

The President:—The next report is that of the Committee on Records and Accounts, which will be presented by the Chairman of the Committee, Mr. H. M. Stout, Record Engineer, Northern Pacific Railway.

(For report, see pp. 431-445.)

The President:—The report of the Committee on Signs, Fences and Crossings will be presented by the Chairman, Mr. Maro Johnson, Assistant Engineer, Illinois Central Railroad.

(For report, see pp. 447-482.)

The President:—In the absence of the Chairman, the Vice-Chairman, Mr. C. R. Knowles, Superintendent Water Service, Illinois Central Railroad, will present the report of the Committee on Water Service.

(For report, see pp. 483-527.)

The President:—The report of the Committee on Uniform General Contract Forms will be submitted by the Chairman, Mr. W. D. Faucette, Chief Engineer, Seaboard Air Line Railway.

The President:—The Tellers appointed at the morning session have just made their report. The Chair will announce the result of the election of officers:

President, J. L. Campbell.

Vice-President, G. J. Ray.

Secretary, E. H. Fritch.

Treasurer, Geo. H. Bremner.

Directors, D. J. Brumley, Maurice Coburn, H. T. Douglas, Jr.

Nominating Committee, A. M. Burt, J. V. Hanna, W. J. Backes, A. O. Ridgway, P. B. Motley.

THURSDAY, MARCH 16, 1922

MORNING SESSION

The President:—The report of the Masonry Committee will be presented by the Chairman, Mr. J. J. Yates, Bridge Engineer, Central Railroad of New Jersey.

(For report, see pp. 541-574.)

The President:—The report of the Committee on Rail will be presented by the Chairman of the Committee, Mr. G. J. Ray, Chief Engineer, Delaware, Lackawanna & Western Railroad.

(For report, see pp. 621-667.)

The President:—The report of the Committee on Economics of Railway Operation will be presented by the Chairman, Mr. L. S. Rose, Assistant to General Manager, Cleveland, Cincinnati, Chicago & St. Louis Railway.

(For report, see pp. 727-774.)

The President:—The report of the Committee on Wooden Bridges and Trestles will be presented by the Chairman, Mr. W. H. Hoyt, Chief Engineer, Duluth, Missabe & Northern Railway.

(For report, see pp. 706-726.)

AFTERNOON SESSION

(The consideration of the report on Wooden Bridges and Trestles was resumed.)

The President:—The report of the Committee on Buildings will be presented by the Chairman, Mr. W. T. Dorrance. Designing Engineer of the New York, New Haven & Hartford Railroad.

(For report, see pp. 775-897.)

The President:—The report of the Committee on Rules and Organization will be presented by the Chairman, Mr. W. C. Barrett, Trainmaster, Lehigh Valley Railroad.

(For report, see pp. 983-1025.)

The President:—The report of the Wood Preservation Committee will be presented by the Chairman, Mr. C. M. Taylor, Superintendent Creosoting Plants, Philadelphia & Reading Railway and Central Railroad of New Jersey.

(For report, see pp. 899-981.)

The President:—This concludes the work of the Standing Committees, and the meeting is now open for New Business.

Mr. W. D. Faucette (Seaboard Air Line):—Mr. President, I desire to offer the following resolution:

"*Resolved,* By the American Railway Engineering Association, in convention assembled, that its thanks are hereby extended to General R. C. Marshall, Jr., Judge James A. Mulligan, and Professor Gus. W. Dyer, for their excellent addresses at the Annual Dinner on the evening of March 15th;

"To the Chairmen, Vice-Chairmen and members of the several committees for their labors during the past year and for valuable reports presented to the meeting;

"To the Committee on Arrangements for the capable manner in which all arrangements for the convention have been carried out;

"To the Technical Press for courtesies extended during the year and also during the convention;

"To the National Railway Appliances Association for the comprehensive and instructive exhibit of railway devices used in the construction, operation and maintenance of railways, and for courtesies extended to the officers and members of the Association."

(The resolutions were seconded, put to vote, and carried unanimously.)

Mr. C. A. Morse (Rock Island):—I desire to offer the following resolution:

"*Resolved,* That the members of the American Railway Engineering Association, in convention assembled, desire to place on record their hearty appreciation of the creditable manner in which this convention has been presided over by Mr. L. A. Downs, and for the efficient administration of the affairs of the Association during his occupancy of the presidential chair.

"*Resolved,* That this resolution be spread upon the Minutes of this meeting, and an engrossed copy be presented to Mr. Downs."

(The resolution was then put to vote, and unanimously carried.)

The President:—The Secretary will read the report of the Tellers.

REPORT OF THE TELLERS

March 15, 1922.

To the American Railway Engineering Association:

We, the Committee of Tellers, report the following as the result of the count of the ballots:

President—

J. L. Campbell 1028
E. H. Lee 1

Vice-President—

G. J. Ray 1024
D. J. Brumley 1
E. H. Lee 1
F. W. Green 1

Secretary—

E. H. Fritch 1029

Treasurer—

Geo. H. Bremner 1025

Directors (three to be elected)—

D. J. Brumley 590
Maurice Coburn 422
H. T. Douglas, Jr. 371
W. P. Wiltsee 357
C. E. Lindsay 355
H. L. Ripley 299
O. E. Selby 271
F. W. Green 190
J. C. Mock 180
R. H. Ford 2
W. R. Armstrong 1
F. S. Schwinn 1

Nominating Committee (five to be elected)—

A. M. Burt	643
J. V. Hanna	611
W. J. Backes	586
A. O. Ridgway	535
P. B. Motley	517
Maro Johnson	458
W. L. Morse	386
A. Montzheimer	373
H. K. Lowry	358
J. deN. Macomb	332
G. H. Tinker	1
E. A. Hadley	1
B. W. Guppy	1
J. R. Leighty	1
H. H. Edgerton	1
R. H. Howard	1
H. T. Hazen	1
E. R. Lewis	1

Respectfully submitted,

P. H. Winchester, Chairman,
J. K. Pettus,
J. V. Johnston,
W. Forrest Ogle,
O. C. Badger,
H. C. Smith,

Tellers.

President Downs:—Your outgoing President wishes to congratulate this convention for having what I consider an excellent meeting. I have attended nearly all of your twenty-three meetings, but never saw so many members in their seats at the opening of the first session on Tuesday morning and so many in their seats in the evening as we have at the closing on the third day.

The attention which the members gave to the proceedings during the convention made it very easy for me to conduct the affairs of the meeting. I believe there has been more said at this meeting that had real weight and less that was relatively unimportant than at any other meeting we have ever held. You are to be congratulated. You have had a particularly good series of reports this year, which will be of great value to railway companies.

I will ask Mr. Morse and Mr. Wendt to escort the new President, Mr. J. L. Campbell, to the Chair.

(Messrs. Morse and Wendt escorted the new President to the Chair.)

President Downs:—Mr. Campbell, you have been elected as President of the greatest body of railway men in the world, a position which but few men merit and a position to which but few have attained. I have watched your work ever since you and I have been in the Association and you well deserve the honor bestowed upon you and I am sure there is no danger of the Association work going down under your direction. I congratulate you. (Applause.)

President-Elect Campbell:—Mr. Downs—If I shall deliver this office to my successor with as much credit to myself as you have delivered it to me, I shall be satisfied. (Applause.)

Gentlemen of the American Railway Engineering Association:—The El Paso & Southwestern Railroad is not a large railroad—only a little more than 1,000 miles in one corner of the country. The honor and distinction which you have conferred upon one of its representatives is an exemplification of the democracy and generosity of this Association. I esteem it a great honor and it is a great delight to be thus distinguished by you. However, I am not presenting any apologies for the El Paso & Southwestern Railroad. Mr. Morse will tell you, if you ask him, that it is a bang-up railroad and, as far as it goes, is just as wide as the Pennsylvania.

I do not view the responsibilities of this office with undue trepidation. On the contrary, I approach them with some confidence solely on account of the men by whom I shall be surrounded, men who will be my advisers and helpers, men whom I have learned to know and love as indeed I have come to know and love all of you with whom it has been my good fortune to come into personal contact and association. For the coming year, I bespeak for the Board of Direction, the chairmen of the standing committees and the committees themselves your heartiest coöperation and assistance. I am sure you will respond promptly to all calls from these committees for your help so that we will gather here again a year from now and duplicate the success and distinction which have marked the convention this year. (Applause.)

Immediately upon the adjournment of the convention the Board of Direction will meet and I especially desire that the Directors elected at this convention will be present.

If there is no further business before you, I now declare the twenty-third annual convention of the American Railway Engineering Association adjourned *sine die.*

The twenty-fourth annual convention of the American Railway Engineering Association will be held at the Congress Hotel, Chicago, March 13, 14 and 15, 1923.

At a meeting of the Board of Direction held March 15, 1922, C. E. Lindsay was elected a Director to fill the unexpired term of the late Colonel Geo. H. Webb, and W. P. Wiltsee was elected a Director to fill the unexpired term of G. J. Ray, promoted to Vice-President.

E. H. Fritch,
Secretary.

MEMORIAL MEETING

MEMORIAL MEETING

JOHN FINDLEY WALLACE

(For Memoir, see Part II, pp. 185-193.)

The President:—We will now hold the Memorial Meeting for John Findley Wallace, our first President, and Colonel George Herbert Webb.

I consider it a great personal privilege to preside here this morning. I regarded Mr. Wallace as a father, and those of you who were active in the last year will recall his address when he spoke of me as one of his boys. He started, like most of us, as a rodman on a railroad out west, and later came to the Illinois Central as Chief Engineer, where I first knew him. He advanced step by step after he left the road, and he went to Virginia, taking me with him, but he remained in Virginia only a few months and came back as Assistant to the Second Vice-President, and finally was made General Manager of the Illinois Central.

He was then appointed by the President of the United States as one of the Canal Commissioners, and later was made its first Chief Engineer. An unusual thing happened at the time of his resignation as Chief Engineer of the Panama Canal. He was publicly rebuked by the Secretary of War, a man who afterwards became President of the United States and is now Chief Justice. It was an unwarranted and uncalled-for action.

I had occasion to visit the Panama Canal in recent years while it was building, and I found that the plans which were originally made by Mr. Wallace were carried out to their completion. All honor to Col. Goethals for completing the Panama Canal, but I say, let us not forget the man who made the plans that were carried out.

Robert Emmett said when he was condemned to die, "Let no man dare, when I am dead, to charge me with dishonor. Let no man taint my memory by believing that I could have engaged in any cause than that of my country's liberty and independence. Let not my epitaph be written until my country takes her place among the nations of the earth; then, and not until then, let my epitaph be written." I say—let not the epitaph of John Findley Wallace be written until a committee of engineers, unbiased by politics, decide whose brains it was that built the Panama Canal.

Mr. Wallace returned from the Canal broken down in health. I visited him quite often at his home, and when he recovered his health he became President of Westinghouse, Church, Kerr & Co., and afterwards he was a Consulting Engineer. He was one of the few engineers who capitalized his brains and reaped a satisfactory dividend from it. He died in the harness July 4, 1921, when he was in Washington to testify before the Interstate Commerce Commission.

I admired Mr. Wallace as an Engineer; I esteemed him as a superior officer on the railroad where I worked, and I loved him as a man. We would be glad to hear from others who may have anything to say.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I deem it a great privilege to be permitted to speak on this occasion of

Mr. Wallace's memorial. My first recollection of Mr. Wallace was about 1893, when I had under advisement some foundation work. I sought Mr. Wallace's advice as to the course which I should pursue in this matter, and he gave me some advice which has been of use to me ever since. At that time I formed such a conception of Mr. Wallace's character and ability, that I believe it has not only had a very large influence on my work in engineering, but I am sure it has had the same effect on many others.

Mr. Wallace's work on the Illinois Central Railroad in the training of apprentices has made a stamp on the conduct of engineering and maintenance work which has been reflected all over this Nation. The President has referred to the unfortunate termination of Mr. Wallace's connection with the Panama Canal. It has been my observation that in nearly all important enterprises undertaken by the Nation, someone must be the pioneer, and that as a general thing that pioneer is also the victim. Mr. Wallace's work on the Panama Canal paved the way for the success of those who followed, and I have felt that his downfall and the treatment which he received was absolutely uncalled for, but I should say that his downfall was merely the course which most pioneers have to necessarily follow in dealing with a question of that kind.

I have no doubt that many of you recall the monograph written by Prof. Charles N. Tilden of Baltimore. It is entitled "The Romance of Engineering." If you have not read it, I would advise you to do so. In that short treatise Mr. Tilden refers to the "Brothers of the Bridge," a society of monks, organized, I think in the second century, whose motto was "To build bridges for those who will pass over them in the future." In my opinion there never was a truer "brother of the bridge" than Mr. Wallace.

Mr. Charles S. Churchill (Norfolk & Western) :—Mr. John F. Wallace, the first President of this Association, overcame difficulties which none but its charter members are acquainted with. In those days every railroad held their standard and other plans much more as personal property than to-day. What their Engineers had accomplished in this direction was regarded as an improvement for that particular road, and not for general distribution to others.

The speaker, attending the early meetings of this Association, noted that its members were somewhat diffident in submitting the plans of the railroads they represented for consideration, also in commenting on plans of others. It therefore became difficult for Mr. Wallace to secure a free discussion on many subjects that were first presented not only on this account, but also because the members were less ready to talk than in later years. The President would frequently urge discussion, using words to the effect: "Even if you have not much to say—say it"; and after great patience displayed, he accomplished his purpose.

Mr. Wallace was a very genial man; much more approachable than many men who occupied positions similar to his, and one who reached the hearts of all the members. It should be recorded of him that he led not only in this project, but in many more, and always succeeded in bringing other men around him who took up his enterprises and carried them on to completion. The members of this Association will always be grateful that John F. Wallace was its first President and leader at the beginning of this great and successful organization.

Mr. W. C. Cushing (Pennsylvania):—My tribute to Mr. Wallace is also because of his being one of the chief founders of this Association, and it was his sponsorship of the Association that hastened my becoming a member of it. I offer, therefore, my sincere tribute to his memory on that account.

Mr. William McNab (Grand Trunk):—As one of the Past-Presidents of this Association, I esteem it a privilege to pay a tribute to the memory of John F. Wallace. Those of us who are not resident in the City of Chicago or along the lines of the Illinois Central, which were the scenes of many of his activities, and were not in the inner circle of his acquaintanceship, will remember him better, as two of the speakers have already said, on account of his activities in the early days of the Association. He was the guiding spirit in the administration of the affairs of this body in its formative stage, as well as in its subsequent development. Through his guiding genius, skill, forethought and interest, this Association has obtained the high standing it has to-day among the technical bodies of the world. Those of us who were present at the first convention twenty-two years ago, will remember some of his statements made at that time—one of which was that the printed Proceedings of the Association in the future would be the textbooks on the several subjects that were dealt with, and that there would be fewer books written by private Engineers on such subjects. How that prediction has been fulfilled, you all know. I have much pleasure in paying my personal tribute to Mr. Wallace's worth as an Engineer and as an administrator.

Mr. A. S. Baldwin (Illinois Central):—I do not think that I can add anything—the facts have been given—in regard to Mr. John F. Wallace, but I cannot allow an occasion of this kind to pass without at least an effort to pay a tribute to him which is due from me on account of my association with him on the Illinois Central Railroad, and my appreciation of his ability and his character.

When I came to the Illinois Central Railroad, Mr. Wallace was the Assistant General Manager. Very shortly thereafter he was promoted to General Manager, and he was only General Manager for a comparatively short time before he went to the Panama Canal. I was with him, however, a sufficient length of time to enable me to appreciate his ability and his character. He was a man of untiring energy. He was devoted to his profession. He had the highest ideals of the ethics of his profession, and certainly he served that profession with great distinction. We remember the passage from the oration of Mark Anthony at the bier of Cæsar—"The evil that men do lives after them, the good is oft interred with their bones"; oft, but not always. The hold that Mr. Wallace had on the hearts of the

Engineers of the country, and above all, on the members of this particular Association, in the formation of which he was so largely responsible, will cause him to live in their hearts and keep his memory green, and all of us should endeavor to see that that memory is kept green and free from stain. That is the duty of those of us who are members of this Association, and which they have seen, year after year, grow from the small institution it was when he started it, to one of the most commanding positions in the world in its particular specialty.

Mr. C. F. Loweth (Chicago, Milwaukee & St. Paul) :—I think it is a high testimonial to the memory of John F. Wallace that such a large number are assembled in this meeting; this Association highly honors itself in setting apart this hour to the memory of one of its founders, its first President, a notable and useful citizen and a true gentleman.

I first met Mr. Wallace more than thirty years ago, and before he became connected with the Illinois Central Railroad. We met briefly in a small town in Iowa. The building of a highway toll bridge over the Mississippi River was under consideration, and the committee having the matter in charge had invited myself and another Engineer, also in private practice, to confer with reference to the engineering services incident to the construction of the proposed bridge. I had made my proposition to the committee, as had also the other Engineer, and they were being considered. In the meantime, while looking the ground over, I was met by a gentleman who introduced himself as Mr. Wallace. He stated that he had heard of the project and had come to the city to inquire about it, and asked me what the status of the negotiations for engineering services were. I explained the matter frankly, as I understood it. He replied, in effect, that as he had not been invited by the committee, and that the matter was at that time so far along, he would not follow it up further, but would take the first train for home. This he did.

I thought at the time and frequently since, that he decided as he did out of what he regarded as the proper professional ethics of the situation. This incident occurred before there was a written code of ethics, or even a generally understood unwritten code governing the ethics of competition between Consulting Engineers in private practice. As in later years I became better acquainted with Mr. Wallace, I often looked back to our first meeting and realized that he was a man whose actions were not conformed to written or unwritten codes of ethics, but rather that his character was of that high order which made his actions those upon which ethics are built upon and formulated.

Although I never knew Mr. Wallace intimately, my acquaintance was not only a source of pleasure and satisfaction but of inspiration, and I esteemed him not only as an able Engineer of the highest character, but as a useful citizen and true gentleman whom it was a pleasure to know and whose memory is cherished.

Mr. C. A. Morse (Chicago, Rock Island & Pacific) :—My first acquaintance with Mr. Wallace was twenty years ago this summer, by accident, on a train. I was connected with the Santa Fe road, and a gentleman riding on the train, who discovered that I was the Engineer of the road, came around and spoke to me, and said he had built the Sibley Bridge on the Santa Fe. I found it was Mr. Wallace. For many years I had the pleasure of meeting Mr. Wallace, and I was one of practically all the Engineers in the country who felt aggrieved at and condemned the criticism of Mr. Wallace in connection with the Panama Canal.

The President:—Mr. G. J. Bell was associated with Mr. Wallace on the Keithburg Bridge. If Mr. Bell is present we will be very much pleased to hear from him.

Mr. T. L. Condron:—I think that everyone who has spoken of Mr. Wallace up to this moment has been a railroad man, and I deem it a privilege to testify to the high appreciation of Mr. Wallace by those who are not in the employ directly of any railroad. I represent the Consulting Engineer members of this Association. Twenty-two years ago I joined this Association at the invitation of Mr. Wallace, and if for no other reason, I have always felt under many obligations to Mr. Wallace for that opportunity of becoming one of the early members of the original American Railway Engineering and Maintenance of Way Association.

There is one thing that is most in my mind about Mr. Wallace, and that is, he was a man of unusual breadth of vision, both as an Engineer and as an executive. He had the vision of the future of this great organization at the very first convention which was held. I think he saw it as it stands to-day. I have considered, and I know we all consider, that it has been a wonderfully useful and valuable adjunct to the entire engineering profession, and as representing those Engineers not in railroad employ, I offer this testimonial of respect and esteem to Mr. Wallace's memory.

Mr. J. L. Campbell (El Paso & Southwestern):—As one of the railway Engineers not having the privilege of a personal association with Mr. Wallace in his work as an Engineer, I wish to add a word in commemoration of his character as an Engineer and a man. Young Engineers of this country as they start out in their work have certain examples before them. The men who are these examples become their heroes and their models. Mr. Wallace was an outstanding figure in the engineering world in that respect and there were thousands of young Engineers all over the country to whom Mr. Wallace and men like him were models and in this respect Mr. Wallace is not dead but still lives. I observe in the testimony being given of his character at this time that, while you are paying tribute to him as a great Engineer you are, fundamentally and back of that, paying tribute to a great man. Back of every great Engineer there is a great man. It requires a great man, a man of sterling character, a man possessing those personal qualifications and character that Mr. Wallace possessed, to make a truly great Engineer—a man who, after his death, will stand a living force in the community. I speak of Mr. Wallace, the man, particularly.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I am glad to say a word at this time in behalf of Mr. Wallace. I was fortunate enough to be under Mr. Wallace as a superior officer of the railroad during the first five years of my railroad career.

I always respected him, and I will never forget my first meeting with Mr. Wallace. I had a table in the draughting room of the general office. My work was on the line most of the time, but I was generally in the office some time during the evening, and I was usually there at 5:30, after every one else was out of the room. Mr. Wallace came in to find someone to fix up a blueprint for him. He looked around the room and naturally came to me, as there was no one else there. I fixed it up for him. It was something that he wanted to send out that night, and he never forgot me from that time. I was surprised and amazed that he remembered my name, and knew me by name, after having come back from the Panama Canal, when I met him in New York one evening. I had not the slightest idea that he would remember me, but he did, and he also remembered my connection with the road.

I had the pleasure during last year to be associated with Mr. Wallace in work in New York. I was a member of a committee that met every week for about three months. Mr. Wallace was chairman of the committee, and I can say he was the same Mr. Wallace he always was, and I was surprised to note how interested he was in all the old boys. I talked with him on several different occasions in the summer about the boys who were with the Illinois Central while he was connected with the road.

I assure you that it is a great pleasure for me to say a word in his behalf. It was a great shock to hear of his death only a week or so after one of these meetings in New York.

Mr. E. H. Lee (Chicago & Western Indiana) :—Circumstances brought me in contact with Mr. Wallace earlier than most of the speakers who have already addressed you. Although I never was intimately associated with him, my acquaintance with him when he and I were first here in Chicago attracted my attention to his ability and force of character. Ever since that time I have watched his progress, and I now feel it a great privilege to say a brief word of tribute to his memory.

From the words of appreciation already spoken, those unacquainted with Mr. Wallace will understand how great was his ability in a technical way, as an executive, as a man of broad mind. His intellect was a jewel having many facets. His career is a good illustration of the fact that great success in any field of endeavor is usually dependent on a combination of great intellectual qualities together with other more homely qualities. He was a typical man whose success may be attributed to the uniform strength in every link of the chain of his characteristics. He had outstanding and shining abilities that attracted men's attention. He had other homelier qualities, not so striking, but which contributed to the unusual measure of his success.

I remember being on a train with Mr. Wallace some fifteen years ago, bound to a convention of the American Society of Civil Engineers. We were the only two men on the train bound for that meeting, and it was therefore my privilege to enjoy his society for the better part of the day. I was surprised at the intimate personal character of his conversation, and the impression I secured was as to his possession of some of the more homely virtues. I am referring to them, as they may be of value to us as men, as railroad men, and as Engineers. One thing that appealed to me in his conversation was his great interest in his friends, the value he set upon them, and the affection he had for them. He realized that friends are any man's best asset.

Another of his characteristics was that he was a man of thrift. He told me of his personal experiences, of his early struggles to make ends meet, and how from the first day that he had ever earned a dollar, he had saved a certain portion of that dollar. He said, "I have lived under the greatest pressure; I was married young; but I have never failed to set aside that same fixed ratio of my earnings from that day to this."

I think that the homely virtues that were so distinctly impressed upon me on that trip—the value of friends, and the need to cultivate them; the value of thrift, and the ability to practice self-denial, in order to secure independence—are things that are well worthy of note in a passing word of tribute to the founder of this Association, the man whose memory we all honor, John Findley Wallace.

Mr. W. M. Camp (Railway Review) :—I can recall so many admirable things about John F. Wallace, whom I knew personally, that I feel I should say something on this occasion. Mr. Wallace was a successful Engineer. His memory will live in history, not only as a great Engineer, but, what is more, as a great man. I have been pleased to hear that side of his character emphasized at this meeting.

I believe that his success depended upon a number of qualities, rather than upon any one in particular. He was a man of sound education, a man of exceptional ability, and he was a broadminded man.

Speaking of his connection with the history of this Association, as others have done, I can easily remember my first meeting with Mr. Wallace, when he sent for me to come to see him. He was then either the Chief Engineer, or Assistant General Manager, of the Illinois Central Railroad. He said to me: "Mr. Torrey and I have put our heads together, and are going to start this Association, and we want you to come in with us." I said: "But, Mr. Wallace, I am out of the railroad service." He replied: "We don't care anything about that. We will have a good many men outside of the railroad service as members of this Association."

I think Mr. Wallace's idea in that respect was to gather into this Association not only men who were actively engaged in railroad service, but others who at any time had had experience of railway engineering—college professors, or former railroad Engineers, who had become contractors or Consulting Engineers. I believe that Mr. Wallace's idea on that combination of experience in the membership of this Association is what has made this Association the institution of worldwide authority that it now stands for.

Another trait of his which gave this Association a very fortunate start was his geniality. He told stories on the platform apropos of matters brought up in the convention, and he tried to make the members feel at ease. If he saw a man of good information on a subject under discussion, but who was modest or hesitant about getting up to speak, he would call him out and interrogate him, and in that way gave to men not ready of speech an opportunity to present their views without the embarrassment that might come to them through volunteering to say something. I also believe that it was Mr. Wallace who originated the parliamentary practice of saving time, by saying: "If there are no objections, this matter will pass," or "will be approved," etc. As I recall it, in the first few meetings of the Association, it was thought to be something unusual in a presiding officer to attempt to speed up the proceedings on matters of ordinary importance in that fashion, without waiting for formal motion and seconding, after enough had been said by way of discussion.

Before the organization of this Association railroad civil engineering questions were handled largely by the American Society of Civil Engineers. As we have here a good many members of that Society, I may remind you that the proceedings of the A.S.C.E. are more or less of a stilted character. For illustration, if one on the floor does not actually speak in the third person, the official report will have him down that way in the proceedings, whether or no. I have heard criticism of the A.S.C.E. on account of the formality of its proceedings. Mr. Wallace dispensed with formality. It was his idea that we should get at the meat of the question that was under consideration and pay less attention to formalities. That was one characteristic that led me to admire the man from the start.

Mr. Wallace was a great Engineer, and he has left monumental works. At first we may refer to the Lake Front engineering of the Illinois Central Railroad. While he may not have been the originator of that plan, he carried out a great deal of it, and, as Chief Engineer and General Manager, he consummated the project.

Another strong point of Mr. Wallace's personality was his courage. I had the pleasure and good fortune to be present at the dinner given to Mr. Wallace when he left Chicago to take charge as Chief Engineer of the Panama Canal. The presiding officer at that dinner was the venerable Octave Chanute. There were perhaps a couple hundred railroad operating officials and railroad Engineers present, and the great fear in the minds of these men at that time was that the Engineers who went down to build the Canal would fall victims of yellow fever. At that dinner the varied experiences in the building of the Panama Railroad were brought up, one of the statements being that as many men died of the fever as there were ties in the track across the Isthmus; and there was enough said at that time to discourage any man to think of going there and undertaking such a work. And, beyond personal considerations, it seemed doubtful whether the Government would be able to keep permanently at work a sufficient force of assistant engineers, because of the unhealthful condition of the climate. At that time the scientific way of getting rid of the yellow fever mosquito—whatever the technical name of that insect may be—was not so well understood as now; but what I want to say is that the tenor of the speaking was rather discouraging to any man who would attempt engineering work in a climate like that.

I remember that finally Mr. Wallace was called upon, and he got up and said that he had not prepared an address, but he wanted to say this: "There are a number of men here who have referred to the unhealthful condition of the climate, and I appreciate fully the risk in that respect, but I am not going to the Isthmus of Panama merely to make a reputation as an Engineer. I am going because my country calls me. The United States has decided to build that canal, and some one has got to go down there and do it; and if I knew at this minute that I would lose my life in the undertaking, still I would go." That will bring out to you, I think, the quality of courage of John F. Wallace.

One of the speakers here to-day used the word "downfall" in connection with Mr. Wallace's leaving that work. I do not think he expected that we should interpret him in the literal sense. It was not a downfall; it was only a temporary drawback, because Mr. Wallace did eminent service for a number of years after that, not only as the head of a great engineering and manufacturing establishment, but as the Chairman of the Chicago Terminal Commission. As another speaker has said, he "died in the harness."

I recall when General Goethals made an address in this city about the time the Panama Canal was completed, and, among other things, he said: "Gentlemen, as an engineering achievement the Panama Canal is not my work. My duties in connection with the enterprise were rather administrative in character. Mr. Wallace and Mr. Stevens, who preceded me, laid out that work, and I adhered to the program which they laid out." If I have not repeated the exact language of General Goethals on that occasion I am sure I have not strayed from the sense of it. We were told that when Mr. Wallace left the Panama Canal there were eighty steam shovels at work.

The credit of making that zone healthful, I believe, is generally given to General Gorgas; but he had the co-operation and assistance of Mr. Wallace in the actual work of clearing the country of yellow fever mosquitos through the use of petroleum. They made Panama an inhabitable and fit place for American citizens to live in, and, before Mr. Wallace left the canal we heard very little of the yellow fever peril.

In my estimation the manner in which Mr. Wallace left Panama will never be remembered against him. It was an unfortunate political turn of affairs. It was not out of consideration of engineering matters at all. While it was a temporary misfortune, he soon outlived it, and I do not think it was very much for a man like John F. Wallace to live down; and, what stands to his credit as a high-minded gentleman, he did not do any talking about it. He kept his feelings to himself and was willing to wait for the verdict of history. I do not recall a single newspaper interview which Mr. Wallace gave out in defense of his position in leaving the Panama Canal.

Mr. Wallace was democratic in his instincts and always approachable. In his chairmanship of this Association there was not much quibbling over small matters. He swept them aside, and he did it in an inoffensive way. He was eminently an American, he was reared like other boys, experiencing the usual struggles and hardships of men who begin at the foot of the ladder; and when he got to the top he did not overlook the favor of his former associates.

Mr. Hunter McDonald:—I used "downfall" spontaneously, and not with any premeditation. The manner in which I used the word "downfall" is illustrated by the careers of a number of leading men in the world, among them Disraeli, who had his downfall; Gladstone, who had his downfall; Poincare, who had his downfall, and they all came back, and so did Mr. Wallace.

Mr. Edwin F. Wendt:—In 1900 the first convention of this Association was held in Steinway Hall, here in Chicago. There were present two eminent Engineers who have passed away, John F. Wallace, our first President in 1900, and John A. Atwood, our Vice-President in 1920. Both these men were very active in the affairs of the Association, and both were charter members. They were eminent Engineers; in fact, they were what we would call railway men, because they understood engineering, particularly in its application to the development of railway transportation. Both of these men had vision of the future. If you will read one of the earliest talks of Mr. Wallace, you will find that he said that the record of the past is the only safe guide for the future. That is the justification for the publication of our Manual. It reflects the experiences of the past.

Mr. Atwood, as well as Mr. Wallace, had a vision of the development of this Association, and the growth of our organization is a great tribute to them.

I want to say that both of these men were of the highest personal character, and both were most eminent railway Engineers.

It seems to me that success does not consist of money or position or title. Success consists of what a man gets out of life, and measured by this spiritual standard, I think that both Mr. Wallace and Mr. Atwood were most successful men.

Mr. G. J. Bell (Atchison, Topeka & Santa Fe):—During the convention of the American Railway Engineering Association at Chicago, March 15, 1922, when tribute was paid to John Findley Wallace, I was not in the room when called on, but am very glad to pay, however inadequate, my tribute to his memory.

I owe him much and am proud to say he was my friend and to have known him intimately was a privilege.

It was my good fortune to start in railroad work with a man like Mr. Wallace. He was large-souled, generous and helpful and many young Engineers, like myself at that time, seeking a start, found it through him. I was with Mr. Wallace almost eight consecutive years and in the later years of my service was quite close to him and remember very clearly his idea was at that time, an organization similar to the present American Railway Engineering Association, to fill a want which societies then in existence did not reach. Later he was one of the leaders who organized this Association and was its first President.

He was one of those rare combinations of thorough ability, good judgment and consideration of the rights of others. A man of strong personality, sterling qualities and keen sense of justice and possessed in a high degree the power to command loyalty from those under him. He was a born leader, very resourceful and his ready grasp and common-sense treatment of an engineering problem in controversy could always be depended on. His reputation in his profession was of the highest order and he was regarded as one of the distinguished Engineers of the country. Such characters are an inspiration to all members of the profession.

He will be missed in the meetings of the Association and the many technical societies to which he belonged.

Mr. Wallace was a gentleman, a man in all the word implies. True to his friends and the world is better for his having lived. He was a man worth while.

The President:—I wish I had time to read you the first annual address of the first President, Mr. Wallace, but I will read you the last paragraph. It is a keynote speech, and could be as well delivered at the meeting to-day as when it was delivered nearly twenty-five years ago:

"While the question of what is economical management respecting maintenance of way and structures is one which the management of each property must solve for itself, we can certainly assist each other by a full and frank comparison of views and a discussion of the various elements that constitute an economical handling of our maintenance of way work. The establishment of certain recognized principles as the result of our investigations and discussions will materially assist our managements in adopting a policy that will lead to the truest and highest economy."

That is an extract from the address of the first President, and gives the keynote to the work of the American Railway Engineering Association.

This will close our exercises for the memory of Mr. John F. Wallace, and Peace be to his memory.

COLONEL GEORGE HERBERT WEBB

(For Memoir, see Part II, pp. 195-200.)

Mr. S. E. Emmons (Ann Arbor):—It was my good fortune to assist Colonel Webb in France, at probably his most trying moment. You no doubt have heard about his work in France, and know that he built the Navarre Cutoff, with ten miles of double track line. He had three thousand men on the job, and had started the work when the War Department, with very questionable judgment, and without warning, took every man away from him. When I came upon him, the same day, I had sixteen men. I found Colonel Webb all by himself, except for a

French interpreter, and he even had to chop the wood to build his own fire. He grabbed hold of me with my sixteen men, and the first thing, that he did was to put guards out on his equipment, and with the utmost good humor and energy, set about to collect his new force, which did not arrive for one month. This shows what he had to contend with in his work in France.

Mr. G. A. Mountain (Canadian Railway Commission) :—In memory of Colonel Webb, the words that fall from my lips will be few. The late Colonel Webb was intimately associated with a good deal of railroad work in Canada, and I speak in behalf of his Canadian confreres as well as myself, and also on behalf of the Government Control Board of Canadian Railways, and I will say this to his fellow-members: That we had always had the strictest confidence in cases that he presented before the Canadian Railway Commission, and the presentation was done in such a manner that there was no doubt left in the minds of that body that his honesty of purpose was shown.

It was only a year ago that I had the pleasure of having quite a conversation with the late Colonel Webb in this hotel. I need not say to you that I was shocked at his state of health, and when I got notice from his Detroit office of his death, I was not surprised, but I was shocked. I then took the opportunity of conveying to the engineering department of the Michigan Central Railroad the feelings of his Canadian brother Engineers.

The late Colonel Webb did not have to be told in his lifetime that he had the esteem and confidence and friendship of his friends of the profession, and it may not be amiss to his memory that the few words I have spoken may come to the ears of his relatives and friends of the feeling which we had for him.

His work as an Engineer we all knew well. That is true of those who were of about his time in life. To the younger members I will say he was an example to those who were closely associated with him, and I hope you will accept these few words of mine with the idea we may always hold his memory dear.

Prof. H. E. Riggs (University of Michigan) :—I want to speak, not as a man who had a very intimate touch with Colonel Webb during my railroad career but as one of a group of men of about the same age, who have been personal friends for years. In the last few years of Colonel Webb's lifetime it was my privilege to know him quite intimately, and it was my privilege to know the feeling of the Engineers of the city of Detroit and the State of Michigan for Colonel Webb.

A great many of us, when we are in the railroad service, are so busy that we do not make the impression on the community that we ought to make, and that we have the ability to make. Colonel Webb, I believe, left on his city and state an impression such as few of you Engineers, whether in the railway service or out of it, have made.

Colonel Webb was a man of genial disposition, a man who was interested in young men, and a man who stood for the finest and the best things in the profession, a man who was a loyal American, and who went overseas at a time of life when one might be expected tô remain at home. It is my privilege to come here to bring a testimonial as to Colonel Webb's worth as a man on behalf of the Engineering Faculty of the University of Michigan, and of the Engineers of Eastern Michigan, who came to know Colonel Webb as a good Engineer, a good citizen and a good and lovable man.

I hope that this Association will always keep his memory green.

Mr. E. T. Howson (Railway Age) :—I desire to pay further tribute to the memory of Colonel Webb. It was my privilege to come in frequent contact with him in recent years, and I never met him but what I came away with a feeling of inspiration. He had the faculty of inspiring those with whom he came in contact in that way.

His engineering work constitutes a sufficient monument to his engineering and executive ability, while the citations which he received in service overseas constitute the monument to the services he rendered our country in the recent conflict. But it is in connection with the inspiration which he was to those with whom he came in contact that I desire to give expression. It was my observation that there are few men who have commanded to the same extent not only the respect, but the sincere affection of their associates, and the members of their organization, as Colonel Webb did, and it was that same impression that he left with those not in his organization, who came in contact with him.

Mr. J. F. Deimling (Michigan Central) :—I would add a tribute from the Engineering Staff of the Michigan Central Railroad, and as Colonel Webb's successor call to your minds the sterling character of this man, his outstanding honesty, and the great regard he had for his subordinates, and those with whom he came in contact in his daily work. This might be well illustrated by telling you that on his deathbed he remembered the family of a deceased employee who were in straightened circumstances, and about one of the last things he did was to provide a Christmas dinner for this family. That shows what the man was. Anyone who knew him, knew of his outstanding honesty. The simplicity of his life, in fact, was such, that probably if he were here to dictate what should be said, he would tell us not to spend too many words on his virtues.

The record he made in the war in the service of his country, and which probably ended his life, are written in the archives of our War Department, and as representing the members of the Engineering Staff of the Michigan Central Railroad I desire to add my tribute to the great worth of this man.

Mr. A. S. Baldwin (Illinois Central) :—I was not a familiar of Colonel Webb's, but met him on a number of occasions professionally. He was a very fine character, and a very able man. I have never dealt with a man whom I believed to be fairer or more straight in his dealings than Colonel Webb was, and at the call of his country he entered the service of the United States, and was in Europe for the entire period of the war. He attained distinction as a Colonel of the United States Army.

COMMITTEE REPORTS

REPORT OF COMMITTEE XIV—ON YARDS AND TERMINALS

A. MONTZHEIMER, *Chairman;*
J. E. ARMSTRONG,
F. J. ACKERMAN,
J. H. BRINKERHOFF,
J. D'ESPOSITO,
A. W. EPRIGHT,
REUBEN HAYES,
J. B. HUNLEY,
F. E. MORROW,
O. MAXEY,
H. J. PFEIFER,
C. E. SMITH,
C. H. SPENCER,
E. E. R. TRATMAN,

HADLEY BALDWIN, *Vice-Chairman;*
C. A. BRIGGS,
MILES BRONSON,
A. E. CLIFT,
L. G. CURTIS,
H. T. DOUGLAS, JR.,
E. M. HASTINGS,
L. J. F. HUGHES,
D. B. JOHNSTON,
B. H. MANN,
C. H. MOTTIER,
S. S. ROBERTS,
J. G. WISHART,

Committee.

To the American Railway Engineering Association:

Your Committee on Yards and Terminals herewith respectfully submits its report to the Twenty-third Annual Convention.

(1) Manual

Considering that a new Manual is to be issued in 1921, it was decided there would be no necessity for changes in the Manual at this time.

(2) Unit Operation of Railway Terminals

On account of the disturbed conditions due to change from Railroad Administration to Corporate Management, it was thought best to continue the subject for another year.

(3) Passenger Station, Freight House and Grain Weighing Scales

Inasmuch as the Interstate Commerce Commission, in its decision in the case Docket 9009, has approved a specification for grain weighing scales in connection with the question of claims for loss and damage of grain, even though such specification is not yet made standard for the railroads, the Sub-Committee has made no study of that subject on its own account.

The Sub-Committee has made progress in the matter of preparing a specification for passenger depot and freight house scales, including motor truck scales, and expects to put before the members of the Association at least a tentative draft thereof prior to the date of the next annual meeting.

(4) Handling of Freight, Etc.

In Appendix A, the Committee submits its report. On account of the rapid development in the art of handling and storing freight in multiple-storied freight houses and warehouses it is recommended that this subject be carried over another year and that a study be made of the various methods of handling L.C.L. freight.

A

(5) Classification and Departure Yards

Report is submitted herewith in Appendix B, as information.

(6) Transfer of Lading of Bad-Order Cars

As the report of this Committee was presented at the 1921 Convention and appears in 1921 Proceedings, it was not thought necessary to submit any further report at this time.

(7) Outline of Work for 1922

H. J. Pfeifer, Chairman; C. A. Briggs, C. H. Spencer, B. H. Mann, J. B. Hunley, *Sub-Committee.*

The work of Sub-Committee (7) has been conducted entirely by correspondence. The following program is recommended:

Subject (1) Revision of Manual.
This subject is always with us and should be continued.

Subject (2) Unit Operation of Railway Terminals.
It is our opinion that study of this subject should, by all means, be continued, as it is far from being exhausted. With it might be coupled a revision of the catechism of unit operation of terminals.

Subject (3) Passenger Station, Freight House and Grain Weighing Scales.
It is recommended that this subject be continued for another year.

Subject (4) Handling of Freight, etc.
Continue study of handling freight by mechanical means, and also report on the relative economies of one and two level freight houses with particular reference to the cost of the various elements of freight handling and the area of land occupied.

Subject (5) Classification and Departure Yards.
Continue study of Classification and Departure Yards.

New Subject: Study and report on best ways of arranging terminals to reduce preparatory leaving time and terminal arriving of trains.

CONCLUSIONS

1. The Committee recommends the following definition for insertion in the Manual:

SORTING YARD.—A yard in which cars are classified in greater detail after having passed through a classification yard.

2. The Committee recommends that reports on subjects 3, 4 and 5 be received as progress reports.

3. The Committee recommends the reassignment of subjects 1, 2, 3, 4 and 5 and the assignment of the new subject contained in report of Sub-Committee (7), for next year's work.

Respectfully submitted,

THE COMMITTEE ON YARDS AND TERMINALS,

A. MONTZHEIMER, *Chairman.*

Appendix A

WAREHOUSES IN CONNECTION WITH L.C.L. FREIGHT HOUSES

C. H. Spencer, *Chairman;*
Miles Bronson,
L. G. Curtis,
H. T. Douglas, Jr.,
J. D'Esposito,
R. Hayes,
L. J. F. Hughes,
E. M. Hastings,
C. H. Mottier,
F. E. Morrow,
E. E. R. Tratman,
J. G. Wishart,
Sub-Committee.

Your Committee has held two meetings in the offices of the Association in Chicago, and submits the following as a progress report:

Some of the principal advantages of constructing warehouses in connection with L.C.L. freight houses may be briefly stated as follows:

(1) The development of the air rights above the freight house for warehouse purposes creates an added source of revenue which helps reduce the charge for high land values which would otherwise be absorbed entirely by the freight house.

(2) The warehouse, by being located on the railroad company's property, attracts traffic to the railroad which might otherwise be lost.

(3) The occupant of the warehouse is saved the usual time and expense necessary to truck his goods between warehouse and freight station. In many locations, where streets are narrow and already congested with traffic, this elimination of trucking is desirable, both from the standpoint of the warehouse operator and the municipality.

The extent and importance of these various advantages depend entirely upon local conditions, and must be determined for each individual location. It might be mentioned in this connection that the operation of buildings above freight stations for light manufacturing and other purposes has proven successful.

Some of the principal disadvantages of constructing warehouses in connection with L.C.L. freight houses may be expressed as follows:

(1) There might be created by this arrangement considerable interference between the employees and patrons of the warehouse and those of the freight station, which would be objectionable.

(2) Railroads are not organized to conduct a warehouse business and some of them are legally restricted from engaging in such activities.

(3) A warehouse operated by a railroad company is governed by the regulations of the Interstate Commerce Commission, which is not the case with a privately operated warehouse company. This places the railroad company on an unfavorable competitive basis with the private company.

In numerous cases the last two handicaps have been overcome by the railroad company by either organizing a subsidiary warehouse company to operate the property or leasing it for a period of years to an independent company.

If a warehouse is to be most successfully operated in connection with an L.C.L. freight house, particularly if the latter is of some magnitude, it is desirable to eliminate interference between employees and patrons of the two facilities. It is, therefore, desirable in so far as possible, without a too great duplication, to provide separate and independent facilities for each. This applies particularly to tailboard space, railroad trackage, shipping platform space and elevator service. Adequate facilities should be provided for the warehouse without interfering with the freight house operation. To do this, it is necessary to determine the amount of trackage, tailboard space, shipping platform area and elevator service required for a given warehouse floor area. (These various elements, for convenience, will hereafter be referred to as factors of design.) If this is not done, and inadequate facilities are provided, it is very probable that the future effectivness of the freight house may be seriously handicapped by the use of facilities for warehouse purposes which were originally intended for the use of the freight house.

The success or failure of a warehouse in connection with an L.C.L. freight house depends very largely upon the proper design and operation of such facilities. Before it is possible to intelligently consider the feasibility of constructing a warehouse above a freight house, the proper relation which should exist between the various factors of design should be determined. Especially is this true if the freight house is of the multiple-story type. With this information and a knowledge of economic height and type of warehouse buildings, it is possible to determine if a warehouse and freight house can both be constructed on the parcel of ground available for that purpose. If these facts are not known, and a warehouse is constructed in connection with the freight house and later found to have insufficient facilities to permit of its complete operation, the result will be very unfavorable.

This is a subject on which very little information is available. Perhaps this is partially due to the fact that so many variables are involved that an exact solution is not possible. However, it is felt that a study of existing warehouses and the experience gained from their operation should be of value in securing a general idea of the relation which should exist between the various factors of design.

A study has been made of fifteen warehouses, and the data collected is here presented as information. Table No. 1 contains general data on the fifteen warehouses selected for the study. This information is supplemented by additional tables which follow in the report.

TABLE No. 1—GENERAL DATA ON WAREHOUSES INVESTIGATED

Reference No. of Warehouse. (Note A)	Date of Construction.	No. of Floors.	AREA OF FLOOR SPACE, SQUARE FEET (Gross—No Deductions Made for Columns, Elevators, etc.) Shipping Platform (Note B)	Storage Space Served by Elevators (Note C)	Total Storage Space (Note D)	Number of Freight Elevators.	No. of R. R. Cars Serving Each House.	Tailboard Frontage, Linear Feet.	REMARKS
1	2	3	4	5	6	7	8	9	10
1	1918	8	44,800	3,894,000	3,894,000	72	93	1824	U.S. Army Warehouse (Note E)
2	1918	8	37,670	1,344,000	1,573,500	24	90	960	U.S. Army Warehouse (Note E)
3	1918	6	19,800	512,000	565,500	7	28	90	U.S. Army Warehouse (Note E)
4	1918	6	(Note F)	600,000	600,000	10	F	101	Over L. C. L. Freight House.
5	1917	3	20,860	561,100	561,100	15	32	F	Over L. C. L. Freight House.
6	1917	7	(Note F)	357,100	357,100	7	F	F	Railroad Warehouse.
7	1917	8	12,110	282,100	282,100	7	20	216	Privately Operated Warehouse.
8	1915	4	22,700	438,300	438,300	6	24	356	Used by One Tenant.
9	1914	8	(Note F)	184,400	184,400	6	F	F	Railroad Warehouse.
10	1912	6	(Note F)	96,600	96,600	4	F	F	Railroad Warehouse.
11	1911	8	7,370	201,800	223,900	4	8	100	Privately Operated Warehouse.
12	1910	8	6,840	230,400	256,300	4	9	100	Privately Operated Warehouse.
13	(Note G)	6	50,400	1,261,400	1,421,000	30	100	1000	Privately Operated Warehouse.
14	1907	5	(Note F)	145,100	145,100	8	F	633	Over L. C. L. Freight House.
15	1901	4	5,950	185,700	221,600	5	11	100	Used by One Tenant.

Wherever floor area is used in this report gross area is considered, no deduction having been made in any case for columns, walls, elevators, checkers' booths, scales, aisles, etc.

NOTE A—The same reference number will be used to designate warehouses throughout all tables in this report. If the identity of any of the warehouses is desired for a further analysis of the information herein presented, same can be obtained from C. H. Mottier, Office Engineer, Illinois Central Railroad, Chicago.

NOTE B—The shipping platform space shown in Column 4 is the platform space adjacent to car siding used for shipping purposes.

NOTE C—The storage space shown in Column 5 does not include shipping platform space shown in Column 4, but does include all other space served by elevators.

NOTE D—The total storage space shown in Column 6 includes all warehouse space except shipping platform space shown in Column 4.

NOTE E—The U. S. Army Warehouses Nos. 1 and 2 are located on seaboard, and are served by both boat and rail.

NOTE F—Facilities of Warehouses Nos. 4, 5, 6, 9, 10 and 14 are used by both freight house and warehouse and, therefore, exact amount used by warehouse is not obtainable.

NOTE G—The first section of Warehouse No. 13 was constructed in 1905, the second in 1908, and the third in 1920.

In order to profit by the experience secured in the operation of these warehouses, the operating officials were requested to suggest any alterations which in their judgment would make a more satisfactory relation between the various facilities. This then permitted not only a comparison of the actual facilities, but in several cases also the comparison of factors which the experience of the operating officials showed were desirable.

Elevators

The question of amount of warehouse space per elevator is one which does not admit of a definite solution and a very great variation might, therefore, be expected. The principal reasons for this variation are the size of warehouse, the number of tenants involved and the wide difference in the length of turnover of goods, size and speed of elevators. As an indication of the prevailing practice as to the size of elevators, the information contained in the Table No. 2 is presented.

TABLE No. 2—INFORMATION ON ELEVATORS

No. of Warehouse	Date of Construction	No. of Elevators Classified as to Capacity in 3'x6' Trucks				Speed in Ft. per Min.	Capacity in Lb.	REMARKS
		1 Truck	2 Trucks	3 Trucks	4 Trucks			
1*	1918	......	....	....	72	150	10,000	Satisfactory.
2	1918	......	....	....	24	150	10,000	Satisfactory.
3	1918	......	....	7	....	150	8,000	Satisfactory.
4	1918	......	....	10	....	350	5,000	Satisfactory speed was determined by requirement of tenant.
5	1917	......	....	....	15	100	10,000	Satisfactory.
6	1917	......	6	....	1	......	....	Elevators of 3-truck capacity are recommended.
7	1917	......	....	6	1	125	12,000	Satisfactory.
8	1915	......	....	6	....	100	8,000	Satisfactory.
9	1914	......	....	4	2	100	10,000	Recommend high-speed, 4-truck, 5-ton elevator.
10	1912	2	2	....	....	......	5,000 / 7,000	....
11*	1911	......	4	....	....	......	8,000	Satisfactory for slow turnover.
12*	1910	......	4	....	....	......	8,000	Satisfactory for slow turnover.
13	†	......	....	30	....	75	5,000	Satisfactory as to size. Recommend high speed.
14	1907	......	8	....	....	......	8,000	Satisfactory, as each tenant has an elevator for his exclusive use.
15	1901	......	5	....	....	......	5,000	Recommend 3-truck capacity.

*Supplemented by whip hoists.
†First section constructed in 1905, second in 1908, and third in 1920.

In order to reduce the many sizes of elevators to a uniform basis, they are listed accordingly to their capacity in number of 3 ft. by 6 ft. trucks, which seems to be the size in use in the majority of the warehouses. The warehouses are placed in order of dates of construction. By referring to Table No. 2, it is evident that the tendency in modern warehouse construction is to install larger elevators. The more recent installations have elevators with a capacity of four trucks, which requires an elevator platform approximately 9 ft. by 17 ft. It is also evident that the capacity of elevators in pounds has been increased in proportion to their size. There has also been a tendency to increase the speed, but as an increase in speed very materially increases the cost of elevators the progress in this direction has not been as rapid as in the size and capacity. The number of floors traveled also functions in determining the proper speed, but as most warehouses do not exceed eight floors in height, the question of speed is not as vital as in some other classes of buildings. In arriving at a suggested area of warehouse floor space per elevator, it is assumed that elevators will be installed of a size sufficient for four trucks, with a corresponding capacity and speed as dictated by modern warehouse practice, which seems to be a capacity of 10,000 lb. per elevator and a speed of 150 ft. per minute. This assumption is also justified by the development in freight house construction, as practically all of the recent elevator installations in freight houses have been of this size elevator.

Table No. 3 shows the actual and recommended area of warehouse floor space served per elevator. The three classifications in the table assist in observing the effect of the length of turnover of goods on the elevator requirements. While the length of turnover is indefinite and, in most cases, not obtainable, the nature of the business handled justifies the classification given. The table indicates a considerable range of values particularly between the storage warehouses and those where the turnover is moderately rapid. Seldom are the exact requirements of a railroad warehouse known at the time of its construction. It is, therefore, very desirable to build a warehouse with a reasonable range of adaptability, so that its usefulness will not be unduly restricted. Of the five railroad warehouses included in this study (Nos. 5, 6, 9, 10 and 14) all have been

TABLE NO. 3—WAREHOUSE FLOOR AREA SERVED PER ELEVATOR

Warehouse No.	Square Feet Floor Area Served per Elevator		Number of Tenants	Size of Elevator in Capacity of 3'x6' Trucks	REMARKS
	* Present	Recommended by Operating Officials			
			Storage Warehouses with Slow Turnover.		
4	60,000	....	Many....	3 Trucks	Satisfactory.
11	50,450	....	General Storage	2 Trucks	Satisfactory Elevators supplemented by Whip Hoists.
12	57,600	....	General Storage	2 Trucks	Satisfactory Elevators supplemented by Whip Hoists.
			U. S. Army Warehouses.		
1	54,084	....	One.....	4 Trucks	Elevators located in batteries Central Control.
2	56,000	....	One.....	4 Trucks	Elevators located in batteries Central Control.
3	73,143	56,889	One.....	3 Trucks	Recommended figure best for moderately rapid turnover.
			Warehouses with Moderately Rapid Turnover.		
5†	37,406	....	Many....	4 Trucks	Satisfactory.
6†	51,014	39,680	Many....	2 Trucks	Recommend 2 additional Elevators.
7	40,300	....	Many....	3 Trucks	Satisfactory.
8	73,050	....	One.....	3 Trucks	If more than one tenant were to occupy warehouse, more elevators would be required.
9†	30,733	....	Many....	3 Trucks	Satisfactory.
10†	24,150	32,220	Many....	1 and 2 Trucks	Present Elevators not taxed to capacity.
13	42,046	....	Many....	3 Trucks	Satisfactory.
15	37,140	....	One.....	2 Trucks	Satisfactory.

*Column 5 divided by Column 7 of Table No. 1.
†Warehouses in connection with L.C.L. freight houses.

NOTE—Warehouse No. 14 has 18,140 sq. ft. of warehouse floor space per elevator, but is not included in above table, as it is divided into relatively small compartments with a view of leasing each compartment to an independent party, which necessitated an elevator for each section. The number of elevators installed was, therefore, dictated by conditions other than floor space and turnover of goods.

designed for moderately rapid turnover and are included under that classification. For this reason, and in order to reduce the effect of variables, only the requirements of warehouses with a moderately rapid turnover will be considered. Information on storage warehouses and others designed for special requirements will be included in all tables for purpose of comparison.

The army warehouses have been designed for a special kind of service. Two of them have their elevators located in batteries with central operator control. This arrangement, while increasing the effectiveness of its elevators, is hardly adapted to the needs of general warehouse service. Their elevator service is also supplemented by numerous derricks, cranes and whip hoists. We must, therefore, be governed principally by the information contained in the third classification of the table. A review of this classification with due regard to comments in the remark column, effect of number of tenants and size of elevators, would indicate that a floor area of 40,000 sq. ft. per elevator is a reasonable allowance. (This allowance might be increased to 60,000 sq. ft. per elevator where the warehouse is used for storage purposes only.)

It might be added in this connection as a matter of interest, that some building ordinances in limiting the space between fire walls automatically limit the amount of floor area which may be accommodated per elevator.

Shipping Platform Space

The information relative to shipping platform space required appears in Table No. 4. By shipping platform space is meant the area of platform adjacent to the railroad siding used exclusively for warehouse shipping. In numerous warehouses this space is made larger than required for shipping purposes in order to provide a small amount of storage space which, under certain conditions, is very desirable. The platform space for the six warehouses under the third classification, Table No. 4, do not include this excess space, but are used purely for shipping purposes. The amount of space actually required in proportion to the total storage area of the warehouse depends largely on the extent to which the warehouse is supplied by rail. The two warehouses in the second classification were designed primarily for rail to boat shipments and for the purpose of our study should not be given as much weight as warehouses included under the third classification. The range of values for warehouses with moderately rapid turnover is from 2.7 per cent to 5.2 per cent, with an average of 3.8 per cent. However, warehouse No. 15 is for one tenant and for a general study of this character should be considered too low.

From the data given it would appear that an allowance of 4 per cent would be ample and should allow some space on platform for storage purposes. The information would indicate that 3.5 per cent might be considered a reasonable minimum allowance.

Table No. 4—Shipping Platform Space

Warehouse No.	Total Shipping Platform Space Sq. Ft.	Total Storage Space Sq. Ft.	Ratio in Per Cent between Shipping Platform Space and Total Storage Space	REMARKS
Storage Warehouses with Slow Turnover.				
11	7,370	223,900	3.3	Satisfactory.
12	6,840	256,320	2.7	Satisfactory.
U. S. Army Warehouses (Marine); Shipments Principally Are Rail to Boat.				
1	44,800	3,894,000	1.2	A portion of the cars supplying this warehouse have no shipping platform and are unloaded by Cranes and Whip Hoists.
	37,670	1,573,500	2.4	
Warehouses with Moderately Rapid Turnover.				
3	19,800	565,500	3.5	U. S. Army Warehouse. Practically all shipments are rail to rail.
5	20,860	561,100	3.7	Satisfactory.
7	12,110	282,100	4.3	Satisfactory.
8	22,700	438,300	5.2	Satisfactory.
13	50,400	1,421,000	3.5	Satisfactory.
15	5,950	221,600	2.7	Satisfactory with one tenant using warehouse.

NOTE—Warehouses Nos. 4, 6, 9, 10 and 14 are not included in this table, as their platform space is used jointly with freight house and the exact amount used by warehouse cannot be determined.

The Amount of Railroad Car Trackage

Table No. 5 contains information on the amount of railroad car trackage. The amount of trackage required depends upon the extent to which the warehouse is supplied by rail and whether the shipments are from rail to rail or from rail to team or rail to boat. It is evident that the trackage requirements should be the greatest when shipments are from rail to rail. The length of turnover also influences the amount of trackage required. Under these conditions a large variation in the amount of trackage provided at various warehouses is to be expected. In most warehouses, particularly if more than one tenant is involved, it is only possible to make one car setting per day. In other cases, where but one tenant is involved, it may be possible to make two or more settings per day. In arriving at an estimate for the amount of trackage required it is felt that an estimate should be sufficient to make possible the operation of the warehouse with one setting per day. By referring to Table No. 5 it is to be observed that Warehouse No. 1 has a very large storage space per car. In all probability, when this warehouse is being operated to full capacity, the cars are pulled two or more times per day as one tenant is involved. As has been the case in preceding tables, we must be guided principally by the data presented in the third classification of the table.

The storage space per car in the six warehouses in this classification varies from 14,105 sq. ft. to 20,196 sq. ft. From the information presented, it would appear that an allowance of 17,600 sq. ft. of storage space per car siding is reasonable.

TABLE No. 5—WAREHOUSE FLOOR AREA PER CAR LENGTH OF SIDING

Warehouse No.	Shipping Space	Storage	Sq. Ft. of Storage Space per Car of Siding	REMARKS
Storage Warehouses Where Turnover Is Slow.				
11	5,820	223,900	27,988	Satisfactory for slow turnover.
12	5,400	256,300	28,477	Satisfactory for slow turnover.
U. S. Army Warehouse (Marine).				
1	42,360	3,894,000	41,871	Warehouse used for reservoir purposes. When boats are being loaded warehouse shipments are supplemented by handling cars direct to docks.
2	37,674	1,573,500	17,483	Satisfactory. (Same Note as for No. 1.)
Warehouses Where Turnover Is Moderately Rapid.				
3	19,800	565,500	20,196	Designed largely for rail to rail service and has proven satisfactory.
5	20,860	561,100	17,534	Satisfactory.
7	12,110	282,100	14,105	
8	22,700	438,300	18,262	Satisfactory.
13	50,400	1,421,000	14,210	Superintendent recommends 19,736 sq.ft. per car.
15	5,950	221,600	20,145	Satisfactory with one tenant using warehouse.

NOTE—Warehouses Nos. 4, 6, 9, 10 and 14 are not included in this table, as their shipping space is used jointly by freight house and warehouse and the exact amount used by warehouse cannot be determined.

Tailboard Frontage

The amount of tailboard space required is dependent upon the frequency of turnover and the extent to which teaming is used as a means of handling goods to and from the warehouse. The warehouses listed in Table No. 6 have been divided into three classes to assist in illustrating the effect of the variables above mentioned on the amount of tailboard space required. The information given for the warehouses under the first classification will not be of value in this study and that under the second classification will be of value for comparative purposes only. Unfortunately, there remain but four warehouses under the third classification where the turnover of goods is moderately rapid and in the case of warehouse No. 15 the tailboard is supplemented by lighterage shipments. The table shows the amount of tailboard frontage in comparison to both the storage space of the warehouse and the amount of railroad trackage. The relation with the former will first be considered. The floors for warehouses 7, 8 and 13 vary from 861 to 1,306, with an average of 1,030.

This is a large range and insufficient data from which to make a very valuable suggestion as to proper allowance of tailboard space, but it would appear from the figures presented and observation of the warehouses that an allowance of 1,100 sq. ft. of warehouse floor space per foot of tailboard frontage is reasonable.

If we use this figure and the suggested 17,600 sq. ft. of storage space per railroad car, it follows that 16 ft. of tailboard frontage should be provided per car. By referring to the fourth column in Table No. 6 under the third classification, it will be noted that the values for warehouses Nos. 7, 8 and 13 vary from 10.8 to 19.8, with an average of 15.7. The values for the last two mentioned warehouses, which are recommended figures, are above this amount. It, therefore, appears that 16 ft. of tailboard frontage per car of siding is a reasonable allowance.

TABLE NO. 6—TAILBOARD FRONTAGE

Warehouse No.	Sq. Ft. of Storage Space per Foot of Tailboard Frontage†	REMARKS	No. of Feet of Tailboard Frontage per Car of Siding*	REMARKS
Warehouses Where Shipments Are Primarily from Rail to Boat or Rail to Rail, and Very Little Teaming Is Done.				
1	2,135	Satisfactory	19.6	Satisfactory.
2	1,639	Satisfactory	10.7	Satisfactory.
3	6,283	Practically no teaming	3.2	Practically no teaming.
4	5,941	Very little teaming	......	Cannot separate between warehouse and freight house (siding).
Storage Warehouse Where Turnover Is Slow.				
11	2,239	Satisfactory	12.5	Satisfactory.
12	2,563	Satisfactory	11.1	Satisfactory.
Warehouses Where Turnover Is Reasonably Rapid.				
7	1,306	Satisfactory	10.8	
8	1,231	Supt. recommends 925	14.8	Supt. recommends 19.8.
13	1,421	Observation indicates that 861 are required	10.0	Observation indicates 16.5 to be correct.
15	2,216	Supplemented by shipment by lighters, which tends to increase this figure	9.1	Supplemented by shipment by lighters, which tends to lower this figure.

*Column 9 divided by Column 8, Table No. 1.
†Column 6 divided by Column 9, Table No. 1.

NOTE—Warehouses Nos. 5, 6, 9, 10 and 14 are not included in this table, as facilities are used jointly with freight house and exact amount used for warehouse purposes is not available.

Summary

Summarizing the foregoing report as to the suggested relation between the various factors of design, we have the following, which are suggested for warehouses where the turnover of goods is moderately rapid.

(1) One elevator should be provided for each 40,000 sq. ft. of warehouse space served.

(2) The shipping platform area should be 4 per cent of warehouse storage floor area.

(3) There should be one car length of track siding for each 17,600 sq. ft. of warehouse storage area.

(4) There should be one foot of tailboard frontage for every 1,100 sq. ft. of warehouse storage area.

(5) There should be 16 ft. of tailboard frontage for each car length of siding.

The above figures do not represent exact limits of design, but are indicative of the proper relation which should exist based on experience of the warehouses studied in this report. An idea of the permissible variation from these figures may be obtained by a review of the foregoing tables.

The Committee wishes to acknowledge its indebtedness to the Illinois Central Railroad for the data which is here presented concerning the Factors of Design of Warehouses.

Handling L.C.L. Freight by the Container System

In the handling of freight by mechanical means a recent development is the use of the container system for moving L.C.L. freight in lots between certain points. This system has been applied mainly to the transfer of freight in cities, but is used also in its transportation between cities. In both cases possibilities have been developed in economy in time, cost, use of cars and freight house space.

City Transfer of L.C.L. Freight

Cincinnati.—The transfer of L.C.L. freight between the freight-houses of different railways by means of motor trucks carrying containers or demountable bodies has been in operation at Cincinnati for about two years. This service, which now includes 35 main and sub-stations on eight railways, is rendered by the Motor Terminals Company in agreement with the railways, and supersedes most of the former trap car service and individual teaming. In 1920, the daily tonnage handled was from 600 to 750 tons, but there is capacity for 1,200 tons, which represents the total daily L.C.L. transfer. The haul ranges from 1 to 9½ miles, with an average of 3 miles. The 5-ton containers average a load of 4¼ tons.

At each freight-house the inbound freight is loaded by the freight-house crew into containers or large boxes which have been placed on the platform. There is a separate container for each destination; that is, for each freight house to which freight is to be transferred. A loaded container is closed and sealed in the same way as a box car. An electric hoist or overhead crane then picks up the container and places it upon the frame of a motor truck for transfer to its destination, which is the outbound freight-house of some other railroad. On arrival at this freight-house, the container is again picked up and placed upon the platform, to be unsealed and unloaded by the freight-house crew. The motor truck thus released takes an empty or loaded container for some other destination.

All movements are controlled by telephone orders from a dispatcher, who is employed by the railroads. In this way the transfer company acts only as a transportation agent, and its work is done under the direction of the railroads. It has nothing to do with the loading and unloading of the containers, but is responsible for loss and damage during transfer. The hoisting equipments were adapted to the conditions at the several freight-houses. Motor trucks of 5-ton capacity are used with demountable bodies 17½ ft. long, 8 ft. wide and 7 ft. high.

St. Louis.—A similar system in operation at St. Louis has several points of difference from the Cincinnati plan. Instead of motor trucks carrying boxes or containers, the Columbia Terminals Company employs wheeled containers which form trailers handled by teams or four-wheel tractors. The trailer has two rear wheels, the front end of the frame being carried on the tractor; but when the trailer is uncoupled a hinged frame with small wheels is lowered to support the front end and permit of the vehicle being moved. Open bodies with side stakes and canvas covers are used, but closed bodies have been considered. In fact, closed bodies are used at Chicago as noted below. Trailers are set out at the freight-house doors and are left to be loaded or unloaded while the tractors couple up to other trailers and proceed on their trips. This system does not require such mechanical equipment as is used at Cincinnati for hoisting and handling the containers. The trailers are of 9-ton capacity and average 6-ton loads.

The operating system at St. Louis also differs from that at Cincinnati, as the transfer company undertakes to handle the freight as well as to transport it. At an inbound freight-house, the company's check clerk loads the trailer and gives the railway a receipt for the freight. When the trailer has been transferred to the outbound freight house of another road, it is unloaded by helpers who obtain a receipt from the railway. The Company is responsible for loss and damage during transfer.

Another feature of the St. Louis plan is that it serves local off-track freight stations, the transfer company accepting freight and billing it direct. The transfer service is operated between 13 freight stations in St. Louis and 12 in East St. Louis, a higher charge being made for transfer across the river, this higher charge being absorbed by the railroads. The transfer company has also 8 off-track stations in St. Louis at which it receives freight from shippers, assembles it for shipment and delivers the consolidated loads to the several railways. Inbound freight is also collected at railway stations (freight) and carried to the transfer company's stations, to be called for by the consignees. This method reduces the teaming by individual firms. The company's equipment includes about 25 tractors and 75 trailers. It handles about 3,000 tons daily, one-third of this being freight transferred from one railway to another.

Chicago.—Another tractor-trailer system is operated at Chicago by the Chicago, North Shore & Milwaukee Railway. This for the purpose of transferring freight between its outlying terminal stations and a downtown off-track station, a distance of over six miles. This station is established as a regular railway shipping plant. The service was introduced to give the electric railway practically the same standing as the steam railways which have freight houses near the downtown district. Both open and closed trailers are used to suit different classes of freight.

Inter-City Transfer of L.C.L. Freight

An experiment with railway transportation of freight and express in containers was begun early in 1921 by the New York Central Railroad but no regular service has been established. A 50-foot low-side gondola car was built to carry the containers, which fitted between the sides with only ½-inch clearances and were secured in place. For freight service it carried two containers of 7,000 lbs. and two of 3,500 lbs. capacity. These were either 14 ft. or 7 ft. long, 7 ft. 6 in. wide, and 7 ft. 8 in. high over all; built of steel frames with wood sheathing and having corner attachments for crane slings.

Loaded containers brought on motor trucks from wholesale houses or other establishments were transferred to the car by a yard crane. When the car was set in the yard at its destination, the containers were picked up by a crane and placed upon motor trucks for delivery to the consignee. The trucking was not done by the railroad company. For handling mail and express matter, the car carried 9 steel containers of 3-ton capacity, these being 9x6 ft. inside, with a height of 7½ ft. This system is being tried for handling freight between Cleveland and Chicago, and mail and express matter between New York and Chicago.

Container Systems on Foreign Railways

Both motor-truck and tractor-trailer container systems have been introduced by several European railways, largely for the store-door delivery service which is common in Europe. The railroad transportation of containers has been used by English railways for some years, particularly in handling mails, baggage and parcels where steamer transfer is involved, as on routes to France and Ireland. The flat cars on which the large sealed boxes are placed are run out on the pier, where cranes transfer them to the steamer. At their destination, the boxes are handled in the same way, being either loaded on cars or placed in the pier shed for unpacking.

Bibliography of Container Handling of L.C.L. Freight

1.—Motor Trucks for L.C.L. Freight Service at Cincinnati.—Engineering News-Record, March 11, 1920; pp. 498-508.

2.—Motor Truck Service for L.C.L. Transfer and Store Door Delivery. —Engineering News-Record, October 21, 1920; p. 785.

3.—Motor Trucks in Terminals Service.—Engineering News-Record, December 16, 1920; pp. 1163, 1194.

4.—Container System for Freight Transportation on the New York Central Railroad.—Engineering News-Record, March 31, 1921; p. 557.

5.—Tractor-Trailer Service for L.C.L. Freight Transfer at St. Louis.—Engineering News-Record, May 19, 1921; p. 852.

6.—Motor-Truck Freight Transfer for European Railways.—Engineering News-Record, June 2, 1921; p. 954.

7.—Tractor-Trailer Freight Service at Chicago.—Electric Railway Journal, July 23, 1921; p. 133.

8.—Motor-Trucks Replace Trap Cars.—Railway Age, Sept. 7, 1917; p. 427.

9.—Expediting Movement of L.C.L. Freight at Cincinnati.—Railway Age, August 6, 1920; p. 219.

10.—Container System of Freight Transportation.—Railway Age, Sept. 24, 1920; p. 515.

11.—Unit Containers for Freight Shipments.—Railway Age, Oct. 22, 1920; p. 684.

12.—Container Car in Express Service on New York Central Railroad.—Railway Age, Feb. 4, 1921; p. 315.

13.—Proposed Container System at New York.—Railway Age, Feb. 25, 1921; p. 474.

14.—Container Car for L.C.L. Service on New York Central Railroad.—Railway Age, April 8, 1921; p. 905.

15.—Container Car in Mail Service.—Railway Age, May 13, 1921; p. 1128.

16.—Standard Freight Container as Auto Truck Body.—Railway Review, June 12, 1920; p. 1015.

17.—Steel Containers Handle Express on New York Central Railroad.—Railway Review, Feb. 5, 1921; p. 214; and April 16, 1921; p. 600.

18.—Expediting Mail Service.—Railway Review, May 28, 1921; p. 811.

19.—The Container System on British Railways.—Railway Review, Sept. 10, 1921; p. 328.

20.—Tractor Method of Handling L.C.L. Freight and Using Demountable Van Bodies for Handling Freight.—Proceedings of Freight Station Section, ARA., 1921.

Appendix B

CLASSIFICATION YARDS, INCLUDING METHODS OF SWITCHING FROM CLASSIFICATION YARDS TO DEPARTURE YARDS.

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Sub-Committee.

A questionnaire in regard to details of design and operation was sent to the railways which had constructed hump yards since the list appearing on page 133 of Volume 15 of the Proceedings was compiled, and a further questionnaire in regard to methods of switching from classification to departure yards, and in regard to the utility of sorting yards auxiliary to classification and departure yards, for more detailed classification of cuts, was sent to these railways as well as to all of the railways previously listed. This report is based upon the replies to these two questionnaires.

New Yards

The Pennsylvania System, Southwestern Region, has built the Hawthorne Yard at Indianapolis, Indiana, consisting of a five-track westbound receiving yard with a capacity of 413 cars, tributary to a fifteen-track westbound classification yard with a capacity of 808 cars, also a five-track eastbound receiving yard with a capacity of 420 cars, tributary to a ten-track eastbound classification yard with a capacity of 750 cars, all of which is described in detail commencing on page 735 of the Railway Age Gazette of October 26, 1917, and on page 514 of the Engineering News-Record of March 14, 1918.

The westbound yard receives a maximum of five trains per hour, and a total of eleven trains per twenty-four hours, averaging forty-one cars in length. There is an average of twenty-one cuts per train, and cars to be weighed are moved to the eastbound yard where the scale is located on the hump. One engine does the work of the westbound yard, acting first as a hump engine and then as a trimmer. An average of nineteen cars per hour, or four hundred sixty cars per twenty-four hours, is now being handled over the hump. Riders walk back to the hump and one rider will handle a maximum of four loads per cut, and an average of twenty-four cars per eight-hour shift. Switches are operated by hand, and the switch tenders are supplied with copies of the switch list. The capacity of this yard is so great as compared with the daily volume of business that no serious congestion occurs in the classification yard and no departure yard is required.

Your Sub-Committee has no detailed information in regard to the operation of the eastbound yard.

The New York, New Haven & Hartford Railroad has built the Cedar Hill Yard, near New Haven, Conn., consisting of a twelve-track southbound receiving yard with a capacity of 1,176 cars and a ten-track westbound receiving yard with a capacity of 970 cars, both tributary to a forty-track westbound classification yard with a capacity of 1,392 cars, which is further tributary to a twelve-track westbound departure yard with a capacity of 1,192 cars, also a fourteen-track eastbound receiving yard with a capacity of 1,490 cars tributary to a forty-track north and eastbound classification yard with a capacity of 1,421 cars, which is further tributary to a twelve-track northbound departure yard with a capacity of 1,140 cars and a fourteen-track eastbound departure yard with a capacity of 1,410 cars, all of which is described in detail commencing on page 1166 of the Railway Age of May 10, 1918, and page 178 of the Railway Age of July 30, 1920.

This yard receives a maximum of four trains per hour in each direction and a total of twenty-four trains westbound and twenty-two trains eastbound for twenty-four hours, averaging sixty to seventy-five cars in length. There is an average of forty cuts per train westbound and forty-five cuts per train eastbound. A scale is located on each hump and cars are weighed in motion. Two engines, one in each half of the yard, do the work, acting as hump or trimmer engines as required. An average of fifty-five cars westbound and forty-five cars eastbound per hour is now being handled over the humps, although with sufficient business and additional riders the capacity of each hump is supposed to be one hundred cars per hour, or twenty-four hundred cars per twenty-four hours. Riders are brought back to the hump on gasoline speeders working on independent tracks, and one rider will handle a maximum of three heavy loads per cut, and an average of fifty cars per eight-hour shift. In accordance with copies of the switch lists, switches are operated by an electro-pneumatic system from towers located at the humps. Departure yards are required to permit of assembling full trains from the short classification tracks and to permit of inspection, air testing, etc., before the arrival of the road crews, thus minimizing terminal delays.

The New York, New Haven & Hartford Railroad has built the Northup Avenue Yard at Providence, R. I., consisting of a nine-track westbound receiving yard, tributary to a seven-track westbound classification yard and a three-track westbound departure yard, also a four-track eastbound receiving yard, tributary to a seventeen-track eastbound classification yard, which is further tributary to a three-track eastbound departure yard. It is necessary on account of topography to classify eastbound trains through this yard in the westbound direction. This yard has a novel development in that a reclassification yard with a separate hump is located between and beyond the regular classification yards, so as to permit of re-humping cars without a second movement over the original humps.

This yard receives a maximum of five trains per hour, and a total of twenty-two trains per twenty-four hours in each direction, averaging forty-six cars in length. There is an average of thirty-one cuts per train. A scale is located on each hump and cars are weighed in motion. Two engines, one in each half of the yard, do the work, acting as hump or trimmer engines as required. An average of forty cars per hour or one thousand cars per twenty-four hours is now being handled over each hump, and one rider will handle a maximum of five empty cars per cut, and an average of fifty-two cars per eight-hour shift. Riders are brought back to the hump on speeder cars working on independent tracks. In accordance with copies of the switch lists, switches are operated by an electro-pneumatic system from towers located at the humps.

The Illinois Central Railroad has planned and partially constructed Markham Yard, a very extensive terminal near Chicago. The ultimate plan provides for a twenty-track northbound receiving yard tributary to a northbound classification yard of seventy-four tracks, which is further tributary to a twenty-track northbound departure yard. Southbound units will consist of a twenty-track receiving yard, tributary to a southbound classification yard of forty tracks, which is further tributary to a twenty-track southbound departure yard, all of which is described in detail on page 1164 of the Railway Age of May 10, 1918, and page 313 of the Engineering News-Record of August 15, 1918.

It is anticipated that the yard will receive a maximum of six trains per hour from each direction, an average of thirty trains northbound and thirty-five southbound per 24 hours, averaging respectively forty to seventy-five cars from the north and from sixty to ninety cars from the south. It is assumed that there will be an average of forty cuts northbound and thirty cuts southbound per train. A scale is located on each hump and cars will be weighed in motion. It is proposed to have two engines in each classification yard—a "pusher" engine crossing over hump, and the "make-up" engine to pull cars from lower end of classification yard to departure yard, making up trains. It is assumed that the average capacity of each hump will be 150 cars per hour, or 3,600 cars per twenty-four hours. Riders will be brought back to the hump on electric or gas speeders working on independent tracks, and it is assumed that one rider will handle a maximum of two cars per cut northbound, where loaded cars predominate, while in the southbound hump where empties will be in majority, riders may handle three, or even four cars. The average both ways will probably be seventy-two cars per eight-hour shift. In accordance with switch lists, switches will be operated by an electro-pneumatic system from towers located at humps.

The Michigan Central Railroad has built the Niles Yard at Niles, Michigan, but your Sub-Committee has no detailed information in regard to it other than that commencing on page 287 of the Railway Age of January 23, 1920, and on page 81 of Engineering News-Record of January 8, 1920.

A further investigation on the part of your Sub-Committee indicates that the Peoria & Pekin Union Railroad has converted its East Peoria Hump Yard to a flat yard; that the Nashville, Chattanooga & St. Louis Railway has temporarily abandoned hump operation at Atlanta, and that the Kentucky & Indiana Terminal Railroad has abandoned hump operation in its Youngstown Yards at Louisville. Further revisions necessary to bring the list on page 133 of Volume 15 of the Proceedings up to date, in so far as your Committee now has information, are the addition of:

Name of Railway	*Location of Hump Yard*
Canadian Pacific Railway	Fort William Winnipeg City Calgary Vancouver
Central R. R. of New Jersey	Penobscot, Pa.
Illinois Central Railroad	Markham (near Chicago)
Louisville & Nashville R. R.	DeCoursey (near Cincinnati)
Michigan Central R. R.	Niles
New York, New Haven & Hartford R. R.	Cedar Hill Providence
Norfolk & Western Ry.	East Portsmouth Williamson West Roanoke
Pennsylvania System	Cape Charles Renova Hawthorne (near Indianapolis)

Hump Yard Design and Operation

An analysis of the information received leads your Sub-Committee to believe that no revisions are necessary in the present recommended hump grades. Although it is probable that these precise grades cannot be used in any given instance, they are a guide as to the grades which will probably be required under given conditions and, if installed, can readily be altered, as may be necessary to meet the exact conditions of any given climate or traffic.

Your Sub-Committee believes that where it is possible to economically construct a classification yard of sufficient length and number of tracks to permit of using it as a departure yard without interfering materially with its operation as a classification yard, a departure yard is not required and is an undesirable addition to the layout. When the volume of traffic is such as to require the constant use of the maximum economical classification yard, or when the tracks in the classification yard are shorter than the usual road train and cannot or should not be extended, a departure yard for the purpose of combining short cuts from several classification tracks into a single road train, and for the purpose of storing this road train during the interval between its assembly and the time of its departure, is of very great advantage in relieving congestion in the classification yard and in minimizing terminal delays. When a departure yard has been installed it may also be economically used for a certain amount of additional sorting of cars by flat switching after they have had a preliminary classification over the hump. It should not, however, be installed primarily for this purpose.

Additional sorting of cars by flat switching at the far end of the classification yard from the hump should be avoided wherever possible on account of the danger of collision between cars being so shunted and those moving by gravity from the hump. When re-sorting of cars becomes of considerable magnitude the number of tracks in the classification yard should be increased or, when this is prevented by topographical or other limitations, the mixed cuts should be re-classified by a second movement over the hump.

When the amount of business will not permit of re-humping cars, relief may be secured by building a flat sorting yard so located that cuts may be pulled from the classification yard by a sorting engine, re-sorted into these tracks, reassembled, and moved directly into the departure yard. If in any case the amount of re-sorting to be done should attain such magnitude that flat switching in this manner is no longer economical, a second hump yard tributary to all or any part of the classification yard, and located between the classification yard and the departure yard in such a manner as to permit of re-humping cars without interfering with the operation of the main hump might be considered. The number and length of tracks required in a sorting yard depends upon the amount of re-sorting to be done and the number of secondary classifications to be made.

Based upon the information now in hand your Sub-Committee believes that in many of the hump yards now in existence a departure yard is not required, and that only in isolated cases where a departure yard is used, would a sorting yard be an economical adjunct.

CONCLUSIONS

Your Sub-Committee is not yet prepared to make a definite recommendation as to when a departure yard, or a sorting yard for intermediate switching between the classification and departure yard, is required, but submits the foregoing as information.

Your Sub-Committee believes that no alterations should be made at the present time in the hump grades as now recommended.

Your Sub-Committee recommends the following definition for insertion in the Manual:

Sorting Yard.—A yard in which cars are classified in greater detail after having passed through a classification yard.

REPORT OF COMMITTEE XVIII—ON ELECTRICITY

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W. L. Morse,
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M. Schreiber,
L. S. Wells,
W. M. Vandersluis,
S. Withington,

Committee.

To the American Railway Engineering Association:

Of the subjects assigned to the Committee on Electricity for study, report is made on the following:

(1) Revision of Manual

No revisions in that part of the Manual which comes within the jurisdiction of the Committee on Electricity are recommended this year.

(2) Electrical Interference

In Appendix A the Committee reports on the subject of Electrical Interference and its recommendations are given in the conclusions.

(3) Water Power

In Appendix B the Committee reports on the subject of Water Power for electric railway operation and its recommendations are given under the conclusions.

(4) Electrolysis

In Appendix C the Committee reports on the subject of Electrolysis and its effect on reinforced concrete and its recommendations are given under conclusions.

(5) National Electrical Safety Code

In Appendix D the Committee reports the result of its review of the National Electrical Safety Code issued by the U. S. Bureau of Standards and submits a commentary thereon.

(6) Overhead Transmission Line Construction

In Appendix E the Committee submits a progress report on the proposed plans and specifications for the construction of overhead transmission and distribution lines and its recommendations are given under the conclusions.

(7) Clearances—Third Rail and Overhead

In Appendix F the Committee submits revisions of the record tables which have been brought up to date and shown on Statement 1, page 1, Data Regarding Third Rail Clearances, and on Statement 2, pages 1 to 6, inclusive, Data Regarding Overhead Clearances. The recommendations of the Committee are given under the conclusions.

(8) Collaboration with Committee XVI—Economics of Railway Location

In Appendix G the Committee reports the result of its collaboration with Committee XVI on the economics of railway location as affected by the introduction of electric locomotives and its recommendations are given under the conclusions.

(9) Standardization

In Appendix H the Committee submits Railroad Specifications for (a) Commercial Adhesive Tape for Electrical Purposes, and (b) Rubber Insulated Tape, for approval and printing in the Manual as recommended practice. These specifications are prepared with the view of standardizing materials and objects in accordance with the recommendation of the Committee on Standardization.

CONCLUSIONS

1. The Committee recommends that the report on Electrical Interference, being Appendix A, be accepted as information, published in the Proceedings and the subject continued.

2. The Committee recommends that the report on Water Power, being Appendix B, be accepted as information, published in the Proceedings and the subject continued.

3. The Committee recommends that the report on Electrolysis and Insulation, being Appendix C, be accepted as information and published in the Proceedings, that the subject be continued and the Committee authorized to continue its representation on the American Committee on Electrolysis and that the report of the American Committee on Electrolysis be accepted, printed in the Manual and in the Bulletin for convenient reference.

4. The Committee recommends that the report on the National Electrical Safety Code, being Appendix D, be accepted as information, published in the Proceedings and the Committee authorized to continue its conferences with the U. S. Bureau of Standards.

5. The Committee recommends that the progress report on Overhead Transmission Line Construction, being Appendix E, be accepted as information, published in the Proceedings and the subject continued.

6. The Committee recommends that the Third Rail and Overhead Clearance Tables, being Statements 1 and 2 of Appendix F, be accepted as information and published in the Proceedings.

7. The Committee recommends that the report on collaborating with the Committee on Economics of Railway Location, being Appendix G, be accepted as information and the coöperation continued.

8. The Committee recommends that (a) the Railroad Specifications for Commercial Adhesive Tape for Electrical Purposes, and (b) the Railroad Specifications for Rubber Insulated Tape, being Appendix H, be approved and printed in the Manual as recommended practice.

Recommendations for New Work

The Committee recommends that in addition to continuing the present uncompleted assignments as enumerated, under the Conclusions, the following new subjects be added:

1. Review the Railroad Specifications for Electric Light, Power Supply and Trolley Lines Crossing Steam and Electric Railways (as printed in the Proceedings, Volume 21, page 208), with the view of bringing the specifications up to date and correcting any minor inaccuracies, in coöperation if possible, with the American Electric Railway Engineering Association, the American Telephone and Telegraph Company and the Western Union Telegraph Company.

2. Study and report on (a) Insulators, (b) Knife and Snap Switches, with the view of preparing plans and specifications for standardizing one or both of these objects, working in conjunction with appropriate committees of the Signal and Telegraph and Telephone Sections of the American Railway Association.

Respectfully submitted,

The Committee on Electricity,

Edwin B. Katte, *Chairman.*

Appendix A

ITEM (2) ELECTRICAL INTERFERENCE

W. M. Vanderluis, *Chairman;*
J. C. Davidson, *Vice-Chairman;*
R. Beeuwkes,
J. V. Duer,
S. Withington,
Sub-Committee.

The Committee was instructed to continue the study and report on electrical interference with telephone and telegraph lines caused by propulsion circuits, including recommendations for eliminating, as far as practicable, interference with signal and telephone and telegraph lines caused by propulsion circuits and adjacent transmission lines.

Previous reports to the A.R.E.A. on the subject of electrical interference may be found as noted below.

A.R.E.A. Proceedings, Vol. 20, 1919, pp. 203 and 204.
A.R.E.A. Proceedings, Vol. 21, 1920, pp. 272-274, inclusive.
A.R.E.A. Proceedings, Vol. 22, 1921, pp. 128-139, inclusive.

On account of the confliction of interests involved in any attempt to mitigate electrical interference troubles, it seemed advisable to secure coöperation of the committee of the T. & T. Section of the A.R.A. handling the subject of inductive interference. Two meetings have so far been held with that committee.

There is attached a statement of the mitigating measures which may be employed, which statement has the tentative approval of Committee No. 7, T. & T. Section, and your Committee.

It will be noted that mitigating measures listed under the three heads "A," "B" and "C" are divided into three sections: *First,* measures which may be employed by the communication companies, including the railroad communication interests; *second,* measures which may be employed jointly by the communication interests, and the power and traction interests; *third,* measures which may be employed by the power and traction interests.

It is recognized that electrolysis should be classed under the heading of "Electrical Interference." This matter has been handled completely by the American Committee on Electrolysis, whose final report is now in print, therefore under this heading reference is only made, for the convenience of the members, to that report, which will eventually appear in the Proceedings of the A.R.E.A.

These various measures have been assigned to members of two Committees, with a view to having worked up a text to cover simple statements of the troubles experienced, together with the method of handling these troubles. This work already is progressing satisfactorily.

Your Committee therefore submits, as a progress report only, the following statement, covering possible mitigating measures which may be employed, and suggests that the Committee be continued with a view to presenting later a discussion of the various items as included in the statement.

In listing mitigating measures, or measures used for other purposes which might mitigate interference, the Committee, at this time, makes no definite recommendations as to their practicability.

("A") Measures to minimize telephone and telegraph interference caused by alternating current propulsion distribution circuits.

Section I

1. Neutralizing transformers in telephone and telegraph circuits.
2. Shunts, filters and drainage coils in telephone and telegraph circuits.
3. Balance of telephone circuits.
4. Transposition of metallic circuits.
5. Insulation of telephone and telegraph circuits.
6. Adjustment of operating current of telegraph circuits.
7. Cables for telephone and telegraph circuits.
8. Carrier circuits.
9. Metallic telegraph circuits.
10. Telephone and telegraph protectors.
11. Shielding conductors.

Section II

12. Relative position of telephone and telegraph circuits and propulsion circuits.
13. Avoidance of common ground connections for power and communication circuits.

Section III

14. Frequent transformer sub-stations feeding trolleys and feeders with provision for sectionalization.
15. Avoidance of stub end feed.
16. Auto-transformers, distribution system as installed on the New York, New Haven & Hartford Railroad.
17. Track booster transformers.
18. Feeder booster transformers.
19. Return feeders.
20. Current limiting reactors.
21. High speed circuit breakers and relays for power circuits.
22. Potential-neutralizing conductors.
23. Reduction of track leakage.
24. Track bonding.
25. Double trolley.

("B") Measures to minimize telephone and telegraph interference caused by direct current propulsion distribution circuits.

SECTION I

1. Balance of telephone circuits.
2. Transportation of metallic circuits.
3. Cables for telephone and telegraph circuits.
4. Carrier circuits.
5. Metallic telegraph circuits.
6. Ground potential regulator.
7. Insulation of telephone and telegraph circuits.
8. Telephone and telegraph protectors.

SECTION II

9. Relative position of telephone and telegraph circuits and propulsion circuits.
10. Avoidance of common ground connections for power and communication circuits.

SECTION III

11. Elimination of tooth ripples in generators by
    - (a) Design of generators.
    - (b) Use of resonant shunts.
    - (c) Phase adjustment of two generators mechanically coupled.
12. High speed circuit breakers with resistance.
13. Flash suppressors.
14. Frequent sub-stations.
15. Return feeders.
16. Track bonding.
17. Reduction of track leakage.
18. Double trolley.

("C") Measures to minimize telephone and telegraph interference caused by transmission circuits for A.C. and D.C. propulsion systems and for other supply lines.

SECTION I

1. Shunts, filters and drainage coils in telephone and telegraph circuits.
2. Balance of telephone circuits.
3. Insulation of telephone and telegraph circuits.
4. Adjustment of operating current of telegraph circuits.
5. Cables for telephone and telegraph circuits.
6. Carrier circuits.
7. Metallic telegraph circuits.
8. Telephone and telegraph protectors.

Section II

9. Relative position of telephone and telegraph circuits and transmission circuits.
10. Co-ordinated transposition of power and telephone circuits.
11. Avoidance of common ground connections for power and communication circuits.

Section III

12. High speed circuit breakers and relays in power circuits.
13. Current limiting reactors and resistances.
14. Design, construction and arrangement of apparatus in high tension lines.
15. Operation and maintenance of high tension lines.

Recommendations

The Committee recommends that the subject be continued with the view of establishing, if possible, recommended remedial measures.

Appendix B

ITEM (3) WATER POWER

W. L. MORSE, *Chairman;* G. EISENHAUER,
R. BEEUWKES, *Vice-Chairman;* R. H. FORD,
J. C. DAVIDSON, *Sub-Committee.*

The Committee was instructed to continue the subject and report on the utilization of water power for railroad electric operation, coöperating, if desirable, with the United States Geological Survey in its Super Power Survey. The report of the Super Power Survey was not available until shortly prior to the conclusion of this report and the Committee therefore was not afforded opportunity to give it the comprehensive study that the importance of the subject deserves.

The following report deals specifically with sources of electric power available for the operation of railroads, within economical reach of the Niagara and St. Lawrence Rivers and tributaries of the St. Lawrence River.

(1) Niagara River

Water Available: The Niagara River is the outlet of Lake Erie, conducting the waters from the immense storage basin of the four upper lakes, located on a plateau above elevation 573 above sea level, into Lake Ontario, at elevation 246 above sea level. Through this river there passes an approximate average of 220,000 cubic feet of water per second. Could all of this water be utilized for the full head of 327 feet, more than seven million horse-power would be developed. However, the fall in the river between the cities of Buffalo and Niagara Falls reduces the head to about 314 feet, which includes the rapids immediately above the falls, the cataract itself and the rapids below. Out of this head at least 300 feet can be obtained as useful in power development, and with all of the water from the river being utilized would produce approximately 6,600,000 potential horsepower. The river being a boundary stream, the water is naturally divided between Canada and the United States, or, the Province of Ontario and the state of New York. Assuming the division of water between the two countries to be equal, each country would then have approximately 3,300,000 potential horse-power.

However, some waters are diverted from the Niagara River for navigation and drainage purposes; for those remaining there are two functions to be performed, namely, the continuation of remarkable scenic spectacles in the falls and rapids, and the production of energy for industrial purposes. A division of the waters for these two uses exists today and will undoubtedly continue to exist, but the actual use for power development may tend to increase until further development would impair the scenic grandeur.

Diversion of water at Niagara Falls is now made under a treaty between Great Britain and the United States and is restricted to a total of 56,000 cubic feet per second, divided 36,000 on the Canadian and 20,000 on the American side. (Each country is entitled to 50 per cent of the waters diverted along the international boundary; the above division is governed by the amount of water taken at other points.)

Colonel J. G. Warren, reporting under instructions from the Chief of Engineers in pursuance to Public Resolution No. 8, 65th Congress, recommends that, after certain remedial works for the purpose of preserving the natural scenery, in so far as is justifiable, have been consummated, a total diversion of 80,000 cubic feet of water per second, 40,000 on the Canadian and 40,000 on the American side, be allowed; 40,000 cubic feet per second of this to be returned to the Maid-of-the-Mist Pool for protection of scenic beauty and ice discharging capacity of the river below the falls, and 40,000 allowed to be used below the lower rapids where the maximum head may be obtained.

The opinion has been expressed that the scenic effect of the water would not be seriously changed by the construction of a submerged dam or weir in the center of the rapids above the crest of the Horseshoe Falls, which would spread the waters from the center of the falls toward the ends, making a more even distribution. This Committee is not in full accord with this opinion, but if done it would doubtless be advantageous in checking erosion to divert more water around the falls; such water would be made available for generating power and is that contained in the 80,000 cubic feet per second referred to above. This diversion is acquiesced in by the Board of Engineers for Rivers and Harbors who believe that the scenic beauty can be maintained with an ultimate diversion of from 100,000 to 110,000 cubic feet of water per second.

From the above it will be noted that Government Engineers are of the opinion that water sufficient to produce approximately 2,000,000 horse-power, 800,000 at plants to discharge into the Maid-of-the-Mist Pool and 1,200,000 at plants below the lower rapids, may be diverted at Niagara; and it is not improbable that a further change may be made in the division between the aesthetic and the commercial and that in time 3,000,000 horse-power may be there developed.

There are now developed on the American side approximately 300,000 horse-power. This will be increased upon the completion of construction work now under way to 400,000 horse-power. There, therefore, remains 600,000 horse-power to be developed on the American side to equal the amount set by Government Engineers at the present limit.

Transmission: Electric power is now being transmitted approximately 250 miles from Niagara Falls and tentative designs and estimates made by the Niagara Falls Power Company indicate that power could be transmitted in large quantities under present conditions to New York City for approximately one cent per kilowatt hour, including generation as well as transmission.

Stability and Continuity: The Niagara River constitutes the outflow from a very large drainage area and lake system which gives it an almost constant flow, slight fluctuations only being caused by weather conditions on Lake Erie which tend to increase or decrease the flow but temporarily. It is doubtful if there exists a more constant and reliable source of energy elsewhere on Earth than that obtained by the development of the waters of Niagara River.

American Side: The present development on the American side at two plants is as follows:

Location	Effective Head Linear Ft.	Using Cu. Ft. Per Sec.	Installed Capacity H. P.	Usual Average H. P.
Niagara Plant	140	9,000	105,000	90,000
Hydraulic Plant	212	10.500	268,500	210,000
Total		19,500	373,500	300,000

These plants belong to the Niagara Falls Power Company. This company is now constructing a 32-foot tunnel to the Hydraulic Plant for the purpose of re-developing the water now going to the Niagara Plant. This water will be used to drive three 70,000 horse-power units, which will add 210,000 horse-power installed capacity to the system and place Niagara Plant in reserve.

The development on the American side will then be as follows:

Location	Effective Head Linear Ft.	Using Cu. Ft. Per Sec.	Installed Capacity H. P.	Usual Average H. P.
Hydraulic Plant				
Original Installation	212	11,100	268,500	210,000
Extension to Original Installation	215	8,400	210,000	190,000
Total for continuous use		19,500	478,500	400,000
Niagara Plant (hold in reserve)			105,000	
Total installed capacity			583,500	

During the hours of peak loads, the Niagara Plant will be brought into commission and will also be used as a standby in case of repairs or shut down at the Hydraulic Plant.

In addition to the above plants, the Niagara Falls Power Company owns the stock of the Canadian Niagara Power Company; the plant is located on the Canadian side of the river, with an installed capacity of 112,500 horse-power and normal output of 100,000 horse-power. The combined American and Canadian plants of the Niagara Falls Power Company will, therefore, have, under present treaty conditions, the following development:

Location	Installed Capacity H. P.	Usual Average H. P.
American Side	583,500	400,000
Canadian Side	112,500	100,000
Total	696,000	500,000

Power from the Canadian side is transmitted to the American side, tied in with the current from the American plants and distributed to American industries. From the 696,000 installed capacity it is believed 100,000 horse-power would be available for railroad electrification.

The specific recommendation of the Government Engineers is that the treaty be modified to allow an increased diversion of 20,000 cubic feet more water per second on the American side. This will develop 600,000 horse-power, a large part of which could be made available for railroad electrification. The enlargement of treaty permits for increased diversion of water is now being considered by both the United States and Canada and will undoubtedly be made by the time that there is a demand for the additional power which such additional diversion will make possible.

Beyond the specific recommendation of the Government Engineers is a further tentative expression of conclusions from their investigations which indicates that the final division allowance on the American side may be at least 15,000 cubic feet of water per second in excess of the specific recommendation already made. This further amount of water would add approximately 450,000 horse-power, making a possible ultimate total on the American side of 1,628,500 horse-power.

Canadian Side: In Canada there are three complete plants in operation, namely:

Location	Installed Capacity H. P.
Toronto Power Company	125,000
Ontario Power Company	200,000
Canadian Niagara Power Company	112,500
Total	437,500

The Ontario Power Company is now owned by the Hydro-Electric Power Commission. This Commission also has in the course of construction the Chippawa-Queenston Canal project, the plant for which will be located below the lower rapids. The canal is approximately fourteen miles long. Starting from the Niagara River at the mouth of the Welland River, it follows the course of the latter, for which the flow has been reversed, for a distance of five miles and thence by open cut around the city of Niagara Falls, Ontario, northerly and northeasterly to an immense forebay that is within one mile of the plateau's edge at Brock's Monument. At the foot of the cliff, immediately below this forebay and on the river's edge, the power plant will be located. In this plant nine 50,000 horse-power units are to be installed. This plant is being constructed from funds subscribed by the various municipalities located within the Province of Ontario, bonds for which are guaranteed by the Province. Each municipality will be allotted its quota according to the horse-power it requires and for which it has subscribed. Its current, therefore, like that from the Toronto Power Company, will be used for the benefit of the Canadian public.

Upon the completion of the plant at Queenston, the development on the Canadian side will be as follows:

Location	Installed Capacity H.P.
Toronto Power Company	125,000
Ontario Power Company	200,000
Queenston Plant	450,000
Total for Canadian Use	775,000
Canadian Niagara Power Co	112,500
Total in Canada	887,500

For the above installations there are available under the present treaty 36,000 cubic feet of water per second, which is insufficient to operate the entire development at capacity. It is, therefore, reasonable to suppose that the Canadians either anticipate an increase in the permits under the treaty rights or otherwise will delay the installation of units at the Queenston Plant, for which the water requirements would exceed the amount allowed; or, place in reserve the Ontario Power Company's plant.

Niagara Falls Junior

This scheme suggests a dam across the Niagara River below the lower rapids a little more than a mile below the Whirlpool where there is low land on the Canadian side between the river and the bluff called Foster Flats. It is claimed by the promoters that the dam will produce a head of 100 feet and utilize all of the water that goes over the cataract together with that returned to the Maid-of-the-Mist Pool from plants adjacent thereto. This would amount to about 180,000 cubic feet of water per second, assuming the treaty to be modified as suggested by Government Engineers, and would produce approximately 1,800,000 potential horse-power.

The method proposed in the construction of the dam is to first build that portion to be located on the Flats at the Canadian side, with openings near the base through which to divert the river's flow while the portion to be located in the river's basin is being built.

The dam proposed has a base about 650 feet wide and gradually tapers to a crowned summit over which ice floes are expected to slide to the waters below the discharge from the plant. It is said it will create a mill pond in the gorge reaching back to the discharge points from plants adjacent to the cataract, the waters from which could all be used except during the periods when ice must be carried over the dam; at such times sufficient water must pass over the dam as is required to keep moving such ice as is taken over the falls by the river.

The mill pond if thus created would destroy the scenic effect now produced by the rapids and therefore must have the sanction of both the Governments of Canada and the United States.

If constructed, it would naturally become an international plant, the current from which should be divided between the two countries.

This Committee is not in a position to express any opinion as to the engineering and economic feasibility of the scheme.

(II) The St. Lawrence Waterway

In the fall of 1919 the Canadian Government accepted the invitation of the United States Government to undertake a joint investigation of the improvement to the St. Lawrence River for deep draft vessels, in the interest of both countries, and for the most beneficial use of the waters. To the International Joint Commission were referred the questions as to the economic advantages to be derived from the improvement, as to the traffic that is likely to be carried upon the proposed route, as to the apportionment of capital cost, of cost of operation and maintenance of the improvements, and as to the best method of improvement, including the draft of water and the development of power. It is expected that the report of the Commission will be submitted to the two Governments during the fall of 1921.

To facilitate the work of the Commission each Government appointed an engineer for the purpose of acquiring data and to prepare complete outline plans for an estimate of the cost of the improvement. W. A. Bowden, Chief Engineer, Department of Railways and Canals, was named by the Dominion of Canada, and Colonel W. P. Wooten, Corps of Engineers, United States Army, was designated by the United States Government. The joint report of the engineers was submitted to the Commission on July 1, 1921.

An abstract prepared by Harrison G. Roby, Principal Assistant to the American Government Engineer, Detroit, Michigan, and published in "Engineering News-Record" September 8, 1921, furnishes the following information.

The total length of the St. Lawrence between Montreal and Lake Ontario is about 182 miles and the difference in elevation is 224 feet. The work of improving the river is made feasible because of three important advantageous conditions. The first is that obstructions to navigation are concentrated in comparatively short stretches. The second favorable to the construction of proposed works is the location of rock ledge within reasonable depths at all sites of necessary structures and at the same time below grades of the proposed canals for a large part of their total length. The third is the large amount of water power made available by the proposed work due to the large and remarkably even flow of the river.

For the purpose of discussing the treatment to be accorded the St. Lawrence it is divided into five divisions as follows:

1. Montreal Harbor to deep water in Lake St. Louis.
2. Deep water in Lake St. Louis to end of breakwater at Lake St. Francis terminus of proposed ship canal between Lake St. Louis and Lake St. Francis.
3. End of breakwater to lower end of St. Regis Island.
4. Lower end of St. Regis Island to Chimney Point.
5. Chimney Point to Lake Ontario.

Of these divisions, the first three lie wholly within Canadian territory. The international boundary line follows the river throughout the fourth and fifth divisions.

The decisions reached as to the improvement to be made in each division to obtain the necessary depth for navigation and to obtain the greatest beneficial use of these waters, are summarized in the following conclusions.

Summary of the Government Engineers' Conclusions and Recommendations: The physical conditions are favorable for improvements for navigation which will be permanent and will have very low upkeep cost. For the project as recommended in the report, the total cost of improvement from Montreal to Lake Ontario is $252,728,000. This is an estimate based on present-day prices (considered to be about 80 per cent above pre-war prices) for a 25-foot depth with such provisions that a 30-foot depth may be secured later without interfering with the use of the waterway. It also includes the cost, to the switchboard, of developing 1,464,000 H.P. The total annual cost of operation, maintenance and depreciation of these works is $2,562,000. Of this sum $1,457,000 is properly chargeable to the operation, maintenance and depreciation of power plants. The estimated cost of increasing the navigable depth throughout the entire stretch to 30-foot at a later date is $17,986,000.

Power Possibilities: Improvement of the entire reach from Montreal to Lake Ontario for navigation alone is feasible, and the development of nearly all the potential power in the river, amounting to 4,100,000 H.P., can be made as co-ordinate parts of schemes for the improvement of navigation when conditions warrant.

The simultaneous development of such a vast quantity of power is not a sound economic procedure, as a market to take this output is not now in existence, and cannot be expected to spring into being at once. The sound method of procedure is to improve for navigation alone those reaches where side canals and locks can most economically be used and where the development of the power at some future time is not interfered with by the proposed improvement, and, in that part of the river where the construction of locks and dams offers the most feasible means of improving navigation, to provide for the development of the incidental power obtainable as a result of the heads created by the dams.

If the improvements are carried on simultaneously it will be possible to complete them in eight years from the time the work is begun, if funds are made available as fast as needed.

(III) Shawinigan Falls, Province of Quebec

Shawinigan Falls are located on the St. Maurice River about fifteen miles due north of that part of the St. Lawrence River known as Lake Saint Peter. The St. Maurice, one of the largest rivers in Canada, has its source at the divide between the valley of the St. Lawrence and the valley of the Hudson Bay, at a point about three hundred miles northwest of Shawinigan Falls. Practically all of its drainage area is now forest and most of the country, not being suitable for agriculture, is likely to remain timbered for many years. The whole area is thickly interspersed with lakes, so that the flow of the stream is naturally more constant than that of most rivers of its size. The river flows in a general southeasterly direction and enters the St. Lawrence River at Three Rivers, Quebec, about one-half way between Montreal and the City of Quebec.

Also on the St. Maurice River are falls at Grand 'Mere about six miles above Shawinigan Falls and at Gres Falls about six miles below Shawinigan Falls.

The La Loutre Dam is located at the headwaters of the St. Maurice, nearly two hundred miles north of Shawinigan Falls. It is 1,300 feet long, 70 feet high and forms a lake 360 square miles in area, impounding many times as much water as the Assouan Dam in Egypt. When full this reservoir contains enough water to generate one billion kilowatt hours in the power plants at Grand 'Mere, Shawinigan Falls and Gres Falls. It will thus be seen that a very large amount of the power which can be developed at the low water stages of the river is obtained by means of this dam.

Three regulating dams have also been constructed on the Manouan River, a large tributary of the St. Maurice. This tributary enters the main river about 120 miles above Shawinigan Falls.

These dams impound about 600 square mile feet of water which is sufficient to generate ninety million kilowatt hours when utilized in the power plants of the Company at Shawinigan Falls, Grand 'Mere and Gres Falls.

The Shawinigan Water Power Company has indisputable rights on the St. Maurice River at Shawinigan Falls and at Gres Falls, and further, controls the power from the development at Grand 'Mere owned by the Laurentide Power Company.

At present the combined generating capacity of this development is 300,000 H.P. With the flow of the St. Maurice River, regulated by the La Loutre Dam great storage basin, which has been constructed by the Quebec Government, the generating capacity at Grand 'Mere and Shawinigan Falls will be about 480,000 H.P. and a future development at Gres Falls will raise this to over 600,000 H.P.

These three power plants, located within eighteen miles of each other on the St. Maurice River, controlled and operated by one company, form a very strong power center. From these plants power is now supplied northeasterly to the City of Quebec, southwesterly to the City of Montreal and southeasterly to Sherbrooke and Black Lake, all of which points are about 75 miles from the Falls.

Summarizing, the installed capacity in electric generating equipment owned or controlled by the Shawinigan Company at these three falls is as follows:

Location	H.P.
Shawinigan Falls Plant No. 1	58,500
Shawinigan Falls Plant No. 2	100,000
Laurentide	82,500
Total electric capacity	241,000

In addition, the Shawinigan Company supplies hydraulic power to the amount of 50,000 H.P. at Shawinigan Falls, thus giving a total power development of 291,000 H.P.

The Shawinigan Falls development was started in 1900.

Plant No. 1 has six units of various makes and designs of 10,000 H.P. each.

Plant No. 2 was completed in 1915 and has five units of modern machinery of 20,000 H.P. each.

Plant No. 2 Extension is under construction and will have, when completed, one unit of 40,000 H.P.

(IV) Water Power Resources of Canada

During the years of 1919 and 1920, the Department of the Interior, Dominion Water Power Branch, made a careful re-analysis and computation of Canada's water power resources. All existing stream flow and water power data, available from Dominion or Provincial sources, has been systematically collated, analyzed and co-ordinated with a view to preparing on a uniform basis from coast to coast, revised estimate of the power available. While the resources have been exhaustively analyzed in so far as the information will permit, only very meager data is at hand in many districts and for many rivers.

Basis of Computation: The figures found below are based upon rapids, falls and power sites, of which the actual existent drop or head possible with concentration is definitely known or at least well established. Innumerable rapids and falls of greater or lesser capacity are scattered on rivers and streams from coast to coast which are not yet recorded and which will only become available for development as more detail survey work is undertaken and completed. This is particularly true in the more unexplored northern districts. Nor is any consideration given to the power concentrations which are feasible in rivers and streams of gradual gradient where economic heads may be created by the construction of power dams, excepting only at such points as definite studies have been carried out and the results made matters of record.

In brief, the figures hereunder are based on definite rapids, falls and power sites, and may be said to represent the minimum water power possibilities of the Dominion. The power estimates have been calculated on the basis of 24-hour power at 80 per cent efficiency on the basis of "Ordinary Minimum Flow" and "Estimated Flow for Maximum Development."

Available and Developed Totals: The recorded power available through the Dominion, under conditions of ordinary minimum flow and within the limitation set out in the foregoing, is 18,255,000 H.P. The water power available under estimated flow for maximum development, that is, dependable for at least six months of the year, is 32,076,000 H. P.

There are installed throughout the Dominion water wheels and turbines to the extent of 2,471,000 H.P. However, it would not be correct to place this figure in direct comparison with the minimum or maximum available power figures quoted above and, therefore, reduce the percentage of the available water power resources developed to date. An allowance must be made for the average ratio between the water wheels installed and the power available.

An analysis of the water power plants scattered from coast to coat, concerning which complete information is available as to turbine installation and satisfactory information as stream flow, gives an average machine installation 30 per cent greater than the six months' flow maximum power. Applying this, the figures quoted above therefore indicate that the *at present recorded water power resources* of the Dominion will permit of a turbine installation of 41,700,000 H.P. In other words, the present turbine installation represents only 5.9 per cent of the present recorded water power resources.

Progress During Past Year: The total hydraulic power development installed during the past year and now nearing completion represents approximately 560,000 H.P. of installed capacity. This figure includes only the initial installation of plants under construction, not their ultimate designed capacity. It is evidence of the manner in which the water power resources of the Dominion are being put to effective and productive use.

Future Growth and Utilization of Water Power: Considering the history of water power utilization in Canada during the past few years in conjunction with the present activity with a view to making some reasonable forecast as to its probable future growth, the following may be deducted. Should the rate of water wheel installation during the past 15 years be maintained, there will be installed, in 1925, 3,360,000 H.P.; in 1930, 4,110,000 H.P.; in 1935, 4,860,000 H.P.; and in 1940, 5,600,000 H.P. There is every reason to anticipate that the rate of growth in utilization will be accelerated rather than retarded. Reference to the foregoing totals of water power available will indicate that this anticipated increase in utilization will not seriously reduce the total reserve. Canada possesses sufficient reserves of water power to meet the anticipated demands for many years to come.

(V) St. Lawrence River Project

There has been suggested a waterway from Lake Ontario to the Gulf of St. Lawrence which, coupled with a power development, proposes to produce 6,625,000 horse-power, at a cost of $1,300,000,000, or without the power development at a cost of $650,000,000.

Since the Canadian and United States Commission is about to report on the "St. Lawrence River to Sea" waterway and has estimated that a channel 30 feet in depth can be developed for $250,000,000, further description of this project does not seem warranted in this report.

(VI) Great Lakes to Hudson Ship Canal

A deep waterway is proposed to be located in New York State between Lake Erie and Lake Ontario and from Lake Ontario to the Hudson River. The details have not been fully developed and as the project does not seem to have attracted the favorable attention of the engineers familiar with the conditions involved, further report is, therefore, deferred at this time.

SUMMARY

1. There are at present at Niagara Falls Hydro-Electric developments under United States control totaling 486,000 H.P., of which amount practically none is available for railroad electrification.

2. There are being developed at Niagara Falls under existing Treaty revisions 660,000 additional H.P., of which 210,000 is on the American side. Of this latter amount 100,000 H.P. is available for railroad electrification and is sufficient for local requirements only.

3. There are possibilities, subject to Treaty revisions, of developments on the American side of 600,000 additional H.P., of which the greater part may be available for railroad electrification. This would be sufficient to furnish power to a large portion of the steam railroads within economical transmission distance.

4. There are existing, or under development, other installations, such as the Canadian Chippawa-Queenston project and that at Shawinigan Falls. Power from these plants is not available for railroad electrification in the United States.

5. There are under contemplation other projects, such as the Niagara Falls Junior and the St. Lawrence Waterway. While such power would be available for railroad electrification, it is not believed that such projects have yet reached the stage where this Committee can report as to their applicability.

6. The transmission of power developed at Niagara Falls is limited in distance only by ability to economically construct and safely insulate the transmission lines.

7. Power from Niagara Falls can be delivered to large consumers, within economical transmission distance, at approximately 1 cent per K.W. Hr., which figure is sufficiently attractive as compared with present cost of steam production to warrant serious consideration as to its use for railroad electrification.

8. Hydro-electric power from Niagara Falls is constant because of the enormous storage reservoir afforded by the Great Lakes. None of the Niagara plants are augmented by steam electric stations common to many other hydro-electric installations.

Appendix C

ITEM (4) ELECTROLYSIS

MARTIN SCHREIBER, *Chairman;*
E. B. KATTE, *Vice-Chairman;*
E. J. CORRELL,
A. E. OWEN,
W. M. VANDERSLUIS,
Sub-Committee.

Your Committee has co-operated during the past year with the American Committee on Electrolysis and can report that substantial progress has been made. The American Committee on Electrolysis have completed a comprehensive report which has the unanimous approval of all the representatives of the following organizations:

American Railway Engineering Association.
American Electric Railway Association.
National Electric Light Association.
American Institute of Electrical Engineers.
American Gas Association.
Natural Gas Association.
American Telegraph and Telephone Company.
American Water Works Association.
National Bureau of Standards.

The report will be distributed before the March meeting of the American Railway Engineering Association in Chicago.

The members of the American Committee on Electrolysis have agreed that its report is complete and up to date and that they have gone as far as is practical until further investigations are made by the Sub-Committee on Research. For the time being the following Sub-Committees' work is therefore complete:

Sub-Committee "A"—Principles and Definitions.
Sub-Committee "B"—Design, construction and maintenance.
Sub-Committee "C"—Methods of making electrolytic surveys.
Sub-Committee "D"—European practice.

The American Committee on Electrolysis further decided that its activities for the present should be confined to the work of the Research Sub-Committee co-operating through the Bureau of Standards. The American Railway Engineering Association has a representative on this Sub-Committee. The American Committee on Electrolysis approved two resolutions of the Research Sub-Committee, subject to the ratification of the parent bodies. Below are the resolutions:

First: That the Research Sub-Committee make studies of the cost of railway systems designed to minimize track drop, and the American Electric Railway Association be requested to take sponsorship for this study, working in co-operation with the Research Sub-Committee.

Second: That it is the sense of the Research Sub-Committee that the work of the Committee can best be financed by asking each organization's representative on the American Committee on Electrolysis, except the Bureau of Standards, to contribute or secure $2,500.00 per year for two years. The former fund to defray expenses of the program of work formulated by the Research Committee.

Your Committee recommends the approval of the first resolution but not the second, which involves a contribution on the part of your Association of $2,500.00 annually for use of the Research Sub-Committee. We believe, however, that your Association should otherwise lend its support to the program. This subject is an important one and we believe the report will show that great progress has been made and this progress, as well as future progress, is only possible through the co-operation of all the organizations forming the American Committee on Electrolysis.

The Committee has nothing to report this year upon the Effect of Electrolysis on Reinforced Concrete, other than to say that experiments have been continued in the laboratory of Swarthmore College and it is hoped that interesting results may form the basis of next year's report on this subject.

Appendix D

ITEM (5) CO-OPERATION WITH THE U. S. BUREAU OF STANDARDS

E. B. Katte, *Chairman;*
D. J. Brumley, *Vice-Chairman;*
R. D. Coombs,
L. S. Wells,
S. Withington,
Sub-Committee.

The Committee was directed to continue co-operating with the U. S. Bureau of Standards in the revision of the National Electrical Safety Code. The third revision of this Code is dated October 31, 1920, and was distributed in April of this year, printed in two volumes of the "Handbook Series" of the Bureau of Standards. The first volume contains the rules and the second is a discussion or an explanation of the rules. This edition of the Code is more convenient in form than previous editions, although there are still many cross-references which renders the Code difficult to comprehend without expert study.

The Bureau of Standards has not accepted all of the recommendations made by your Committee referred to in its report contained in Volume 21, No. 221, and Volume 22, No. 231, of the Bulletin, dated, respectively, November 1919 and 1920. The most important of the unaccepted recommendations pertain to the crossing of overhead wires and cables over railroad rights-of-way and involve a reduction by the Bureau of Standards of established railroad standards for structural strength and for clearances.

The Committee has prepared with considerable care the following Commentary on the National Electrical Safety Code, with the object of acquainting the members of the Association with the manner in which it can be used to advantage and wherein the Code requirements differ from accepted railroad practice.

Commentary

National Electrical Safety Code—Third Edition

Scope and Intent: The Code is a compilation of rules intended to state the minimum requirements for spacings, clearances and strength of construction for electrical appliances (p. 78). They are not complete specifications, but are intended to embody the requirements which are most important from the standpoint of safety, to employes and the public (p. 77). They may be varied from particular requirements when circumstances warrant different practice (p. 10). More ample spacings and clearances or greater strength of construction may be provided if other requirements are not neglected in so doing (p. 78).

Note—The page numbers refer to the Code.

Form and Status: The Code, although issued by a Government Bureau, does not have the status of mandatory law until it is adopted by Public Service Commissions or other State or Municipal authorities.

It is not in the form of a law or a designing specification but is useful as the basis upon which a law or a specification can be formed. It should not be adopted as a law or a specification without careful consideration of the conditions of the particular location to which it is to apply and modified to suit those conditions with adequate factors of safety.

The Code consists of two classes of rules: those intended to be mandatory in which "shall" or "must" is employed and those of an advisory or recommendatory nature in which "should" or "may be" is employed (p. 6): when made law to the extent it employs "shall," in connection with construction it has more force than an ordinary specification. Every section is therefore of importance and should be carefully studied.

Division of the Code: The Code is divided into four main parts, which are preceded by sections defining the terms employed and a section on grounding.

Part 1. Contains rules for the installation and maintenance of electrical supply stations and equipment.

Part 2. Rules for the installation and maintenance of overhead and underground electrical supply and signal lines.

Part 3. Rules for the installation and maintenance of electrical utilization equipment.

Part 4. Rules to be observed in the operation of electrical equipment and lines.

Second and Third Editions Compared: In the third edition of the Code the discussion has been separated from the rules themselves and placed in a separate handbook. There is little to criticize and much to commend in Parts 1, 3 and 4. The main criticisms of this Committee is to certain clauses of Part 2, which reduce the requirements for overhead wire crossings over railroads to a point considered unsafe by railroad engineers.

There are many cross-references, and until all of those are consulted and their effect estimated in modifying a given section, the full meaning of that section remains in doubt, thus rendering the Code unduly cumbersome and detracting from its value as a book of reference.

In general the requirements of the Code are more than met by the railroads in the construction of electrical supply lines paralleling railroad rights-of-way. With respect to such lines compliance with the Code should not entail additional expense for construction.

Value of the Code: The Code is valuable in establishing a not impossible standard of safety that can be adopted and maintained by the railroads. Most of the comments of the Committee on the Code will be found to be in the direction of securing greater safety. The comments of this Committee should be regarded as suggestions to perfect the Code and render it acceptable to the railroads in its entirety.

Manner of Using the Code: Inspection of the Code will show that it requires careful study by an expert to fully determine the requirements. It is not therefore suitable to be placed in the hands of workmen for interpretation. It is valuable as a reference book for use in the preparation of rules and specifications. Used in this manner the Code will be found most helpful. Rule 550 (a) (p. 323).

Comparison with A. R. E. A. Crossing Specifications: The following detailed comments relating to Part 2 are the result of a direct comparison with the A. R. E. A. Railroad Specifications for Electric Light, Power Supply and Trolley Lines Crossing Steam and Electric Railways (Bulletin, Volume 21, No. 221, November, 1919, and in the Proceedings, Volume 21, 1920, page 208).

Detail Comments

Section A—Rules Covering Methods of Protective Grounding

Rule 94 (a) (p. 27). Exception is taken to the general plan of grounding circuits, equipment and arresters to the water pipes in steel frame buildings where the water pipes are in contact with such steel work. Water mains are usually carrying more or less current and the above connection permits part of such current to enter upon the steelwork of the building affecting such structures electrolytically.

In steel buildings the water and gas pipe should have an insulated coupling placed at the place of entrance in the line. Electrical connection may then be made outside such coupling on the water main side or to the steelwork of the building provided such steelwork is well grounded.

Part 2 (p. 73)—Rules for the Installation and Maintenance of Overhead and Underground Electrical Supply and Signal Lines

General

A survey of one of the large railroads shows that approximately 75 per cent of the crossings are of 2,200 volts or under. The sections relating to such crossings are therefore of corresponding importance.

The code would be materially improved by separating the rules for supply lines from those for signal lines and placing the latter in a separate part. Supply lines and signal lines are handled by entirely separate interests and the commingling of the rules relating to them, while saving some space, leads to unnecessary confusion.

Rule 210 (p. 82). **Grades of Construction:** The general grades of construction A, B, C, D and E mentioned in various paragraphs of the code are not clearly defined. This is a serious defect in relation to a fundamental matter that should be corrected.

Rule 212 (f) (p. 84). **Anchor Rod:** Delete the words "except in rock or concrete" and insert the words "wherever possible."

Rule 213 (a) (p. 84). **Insulators Where Required:** Head guys should have two insulators in them; one near the pole guyed and the second near the anchor pole.

Rule 218 (b) (p. 89). **Minimum Size of Conductors:** At railroad crossings, No. 8 A.W.G. is permitted. Should be not less than No. 6 H.D. for potentials less than 5,000 volts and No. 4 A.W.G. for higher potentials. No soft drawn wire should be permitted.

Rule 220 (a) (p. 90). **Clearances of Conductors and Wires at Crossings—Table 3:** The code calls for a clearance of 28 feet above rails at supply line crossings at 60 deg. Fahr. for circuits between 300 to 1,500 volts. Most crossings are in this class.

The railroads call for 30 ft. clearance under the most unfavorable conditions for the above potentials. A temperature of 120 deg. Fahr. will make a wire sag more than will the maximum ice and wind loads at 0 deg. Fahr.

The difference between the sag of a No. 4 A.W.G. wire in a 150 ft. span at 60 deg. Fahr. and 120 deg. Fahr. is 11 in. Therefore the code permits a wire elevation 2 ft. 11 in. less than the railroads wish under the above conditions.

For higher voltage the code specifies 30 ft. at 60 deg. Fahr., which is 11 in. lower than it should be.

Exception is also taken to the 27 ft. permitted for supply lines at less than 300 volts.

The clearance below 50,000 volts should not vary with the potential, as the protection desired is against mechanical interference, not to avoid shocks.

In Table 3 it should be made clear that the 16 ft. clearance permitted in the last column applies only to trolley tracks.

Note (b) Under Table 3: Where trolley wires are only 21 feet high they should be raised and not continued at a dangerous level.

Rule 220 (p. 93), Table 4. **Wire Crossing Clearances in Feet.**

This table permits only 2 ft. clearance when supply wires of 0 to 7,500 volt potential cross over other wires of 0 to 750 volt potential, and 4 ft. when the potential is increased to 50,000 volts.

These clearances and others in the table are inadequate. They should be not less than 8 ft. for circuits over 5,000 volts alternating or 750 volts direct current and not less than 4 feet for other circuits.

Rule 221 (p. 95), Table 5. **Minimum Line Conductor Clearances and Separations at Supports.**

Many of the clearances in this table are inadequate.

(a) **Horizontal Separation:** The additional clearance for each kilovolt should be 0.75 in. in place of 0.4 in.

(b) **Clearance From Surface of Poles, Etc.:** The minimum clearance for circuits up to 10,000 volts should be 9 in. in place of 3 in. or slightly over. At 70,000 volts the clearance should be 24 in. in place of about 19 in.

(c) **Clearance From Span and Guy Wires:** These are inadequate in the same proportion as (b).

Rule 225 (p. 101). **Climbing Space:** The climbing space for higher voltages is insufficient. At 70,000 volts the climbing space is only

36 (Sec. 225) (c) to 30 in. (Sec. 225) (a) (2), depending on whether the poles are to be climbed with circuits above or not. This should be nearer 48 in.

At less than 15,000 volts a 24 in. climbing space is permissible by the code (Sec. 225 (c) Note p. 102).

Rule 228 (c) (d) (p. 107). **Clearances Over Buildings:** Clearances should be 10 ft. for circuits 0 to 15,000 volts as well as for circuits of higher voltage.

Rule 229 (p. 108). **Clearances From Bridges:** The code has a varying range of clearances according to voltages. The minimum clearance should be 6 ft. where not attached.

Rule 235 (p. 115). **Signal Lines Over Railways—Sub-division (b) 2:** This permits Grade E construction over branch railways where no regular schedule of operation is maintained.

This rule should be eliminated because there are many branches of railroads which have no regular train schedule that carry at times as much traffic as the main line. Such roads extend around Cleveland, Indianapolis, Chicago and other cities. There are other branch railroads over which large irregular traffic is maintained but not by schedule as, under present methods of dispatching and operating trains, schedules are not necessary as they formerly were.

Section 24. **Specification for Strength of Grades A, B and C Lines.**

Rule 241 (p. 117). It would be better in all cases to give loading conditions for each grade of construction rather than in ratio to the requirements for another grade.

The loadings should be expressed as follows:

Heavy Loading: Wind pressure 8 lb. per sq. ft. on ice covered diameter of wires, ice coating ½ inch radial thickness, temperature 0 deg. Fahr.

Medium Loading: Wind pressure 8 lb. per sq. ft. on ice covered diameter of wire, ice coating ¼ inch thickness, temperature 15 deg. Fahr.

Light Loading: Wind pressure 8 lb. per sq. ft. on diameter of wires, ice coating none, temperature 32 deg. Fahr.

A study of the wind and sleet storm data suggests these alternate loadings.

Heavy Loading Alternate: Wind pressure 20 lb. per sq. ft. on diameter of wires, ice coating none, temperature 0 deg. Fahr.

Medium Loading Alternate: Wind pressure 15 lb. per sq. ft. on diameter of wires, ice coating none, temperature 15 deg. Fahr.

It is also believed to be desirable to change the light loading from 8 lb. wind to 10 lb. per sq. ft., using no alternate loading.

Rule 242 (b) (p. 118). **Assumed Transverse Loading:** This paragraph should, in our opinion, be changed to call for the same loading as that specified in Paragraph 241 for Conductors, with the addition that pressures on flat surfaces should be specified.

These recommended loadings are all given in the following table:

	Surfaces	Ice on Wires	No Ice on Wires
Heavy Loading	Cylindrical	8 lb.	20 lb.
	Flat	13 lb.	32 lb.
Medium Loading	Cylindrical	8 lb.	15 lb.
	Flat	13 lb.	24 lb.
Light Loading	Cylindrical	.....	10 lb.
	Flat	.....	16 lb.

Rule 243 (a) (p. 119). **Strength of Steel Poles:** The permissible unit stresses specified in this paragraph are too high for crossings over railroads. We would recommend that for crossings over railroads the unit stresses specified in the Joint Crossings Specifications should be used, with the exception that we believe that the formula for permissible compressive stress should be changed. The stresses which we would recommend should be adopted are as follows:

Structural Steel—
- Tension ....18,000 lb. per sq. in.
- Shear ....14,000 lb. per sq. in.
- Compression ....15,000—75 L/r

Bolts, Rivets, Pins—
- Shear ....14,000 lb. per sq. in.
- Bearing ....28,000 lb. per sq. in.
- Bending ....28,000 lb. per sq. in.
- Guys ....⅓ ultimate strength.

Note (p. 120): Guys should be made of steel wire having an ultimate strength of about 75,000 lb. per sq. in.

Rule 243 (b) (p. 120). **Guys:** The use of guyed wide base steel towers is very objectionable in that the stresses in such structures are essentially indeterminate. If such a construction must be resorted to the guys should have sufficient strength to withstand, in the direction in which they act, the horizontal component of all the forces acting upon the tower.

Rule 243 (c) (p. 120). **Total Minimum Strength (e) Tests:** With the loads and unit stresses recommended above, these paragraphs are unnecessary and should be omitted.

Rule 243 (g) (p. 121). This paragraph should be modified to provide that no material less than ¼-inch in thickness shall be used in structures at railroad crossings.

Rule 244 (a) (b) (c) (p. 121-122). **Strength of Wood or Concrete Supports:** The selection of a better quality of material does not justify a reduction in assumed loadings. If any change is to be made it should be made in the permissible fiber stress. The factor of safety in wooden poles should be greater six than two, as permitted by this code.

In Rule 244 (a). Fifty per cent should be changed to 33 per cent.

Rule 244 (c). Is objectionable but it does not apply to crossings over railroads.

Rule 245 (b) (p. 123). Fifty per cent. should be reduced to 33 per cent.

Rule 245 (e) (p. 124). **Pins Note:** Code permits wooden pins, which deteriorate and are not as strong as metal pins.

Rule 246 (b) Table 9 (p. 125). **Conductor Materials:** No conductor smaller than No. 6 A.W.G. should be permitted up to 5,000 volts and none smaller than No. 4 for higher potentials.

Code permits No. 8 for B and C Grades in 150-foot spans and No. 6 for higher than 5,000 volts in span of same length.

Rule 247 (a) (p. 127). **High Voltage Insulators:** A.R.A. specifies porcelain insulators. Code permits "other material."

Rule 247 (e) (p. 128). **Factory Tests of High Voltage Insulators.** Code gives a table of Test Voltages and the A.R.A. of Flashover-Voltages. By comparing the two tables it will be seen that the code potentials should be raised in the lower range of potentials.

Section 25. Requirements for Supply Line, Including Electric Railway Feeders

Rule 257 (p. 138). **Wire Clearance Above Railways.**

(1) Code permits 22 feet at 60 deg. Fahr., which does not provide the same clearance "as under the most unfavorable conditions of loading" clause in the A.R.A. Specification, which is that due to 120 deg. Fahr.

(2) Under the second condition the minimum clearance should be not less than 22 feet under the most unfavorable conditions of loading.

Rule 260 (p. 139). **Grades of Construction:** Grade B construction should not be permitted over any part of a railway right-of-way. (See Comment under Rule 235.)

Rule 263 (p. 140-141). **Wire Clearances Above Rail.**

(a) (2). This should be not less than 30 feet for potentials over 750 volts.

Rule 263 (b). No clearance of trolley wires less than 22 feet should be permitted. Specifically the 16-foot clearance herein permitted is objected to.

Rule 264 (p. 142). Code clearances vary from 2 to 6 feet. Should be 8 feet for 5,000 v. A.C. and 750 v. D.C. and 4 feet for other circuits.

Section 27. Supply Lines Over Signal Lines and Joint Use of Poles

Rule 270 (c) (p. 145). **Wire Clearance Above Signal Wires:** Clearance should be increased to agree with A.R.A. Specification.

Rule 272 (d) (p. 147). **Special Provision Regarding Transverse Strength, Also (e) Longitudinal Stresses:** These provisions should not apply to railway crossings.

Rule 281 (p. 153). **Transverse and Longitudinal Strength.**

(a) Transverse guying.

(1) Medium and light loading should not be expressed as two-thirds and four-ninths of heavy loading. Their values should be stated independently.

Rule 281 (a) (1) (p. 153). **Heavy Transverse Loading:** The last two sentences, reading: "In computing the transverse pressure on conductors, the actual number of conductors shall be used up to 10. For larger numbers of wires, only two-thirds of the total number shall be counted, with a minimum of 10, should be eliminated, because there is no engineering authority which will substantiate this method of computation. While Rule 281 gives fairly good strength at the crossing poles by providing an initial factor of safety of 2 for side-guyed poles and an initial factor of safety of 4 for unguyed poles, by neglecting one-third of the wires over 10, it will reduce the factor of safety below what should be considered good engineering. With the uncertain factors entering the problem, such as the actual strength and condition of timber poles, the unreliability of data regarding wind and ice, it seems that a factor of safety of 2, without neglecting any of the factors, is as small as should be permitted. In neglecting one-third of the wires in computing the transverse loading, the Bureau took into consideration an alleged shielding effect. After careful investigation, your Committee could find no scientific data to substantiate the shielding effect theory, and it seems that, in view of the small factor of safety of 2 generally provided for side-guyed poles, no allowance should be made on account of the shielding effect of one wire upon another.

Practical experience demonstrates that wires with sleet on them, when the wind is blowing hard, are not on the same plane, even if strung on the same crossarm, and they vibrate to such an extent that any appreciable shielding effect would not occur.

Rule 282 (c) (p. 155). **Guying in Special Cases:** Side guying of poles 500 feet from crossing will be of no value in strengthening the crossing structures.

Rule 284 (p. 160). **Signal Line Clearances.**

(a) Clearance of 18 feet for tracks carrying traffic where brakemen do not ride on cars should be increased to 25 feet.

(c) There should be added in the middle of this section "at loading sidings sufficient space shall be left for a driveway."

Part 4. Rules to be observed in the Operation of Electrical Equipment and Lines (p. 287, Rule 400).

Rule 400 states that "the employer shall furnish to each regular employe . . a copy of these safety rules . . . (or such of these rules as apply to his work), either separately or incorporated in more comprehensive rule books." Inasmuch as the rules included in the National Electrical Safety Code are of a very general nature it would be fairer to modify the provision to the effect that an equivalent of the safety rules best suited to individual needs might be used. The wording of paragraphs (a) and (b) Rule 550, page 323, is suggested.

CONCLUSIONS

1. The Code purports to establish a National Standard of Safety for the users of electrical apparatus. In general the standard is satisfactory and in accordance with good practice.

2. The rules establish minimum requirements. Greater margins of safety are not prohibited. The Committee does not therefore fail to support the Code when as in the case of Part 2 it suggests greater safety provisions (p. 78, Sec. 203, note).

3. It was not the intention of the Bureau of Standards that the Code should be regarded as a designing specification. It is therefore not inconsistent that the Code be supplemented by working specifications that specify factors of safety not less than those established by the Code.

Recommendations

The Committee recommends that the Railroad Specifications for Electric Light, Power Supply and Trolley Lines Crossing, Steam and Electric Railways, adopted by the Association, and printed in the Proceedings, Volume 21, 1920, page 208, be opened for revision with a view to make them conform with the Code as far as consistent with established railroad standards, conferring with other interests giving special attention to the following items:

(1) Definition of the Grades of Construction.
(2) Minimum Overhead Clearances.
(3) Clearances between Lines and between Conductors and Supports.
(4) Minimum size and material of conductors.
(5) Unit Stresses in Steel and Wooden Crossing Supports (Factors of Safety).
(6) Grounding of Arms and Guys.
(7) Grade of Construction on Branch Lines.

Appendix E

ITEM (6) OVERHEAD TRANSMISSION LINE CONSTRUCTION

S. WITHINGTON, *Chairman;*
R. D. COOMBS, *Vice-Chairman;*
H. M. BASSETT,
F. D. HALL,
L. S. WELLS,
R. BEEUWKES,
Sub-Committee.

The Committee was instructed to study and report on overhead transmission and distribution line construction for railroad use, and prepare plans and specifications for such construction, coöperating with the appropriate committees of the Signal Section and Telegraph and Telephone Section of the American Railway Association. The Committee has collected considerable data which is available for future use. The following paragraphs are presented as preliminary information and a proposed outline of policy.

The Telegraph and Telephone Section of the American Railway Association has done valuable work towards standardizing pole line construction for telegraph and telephone lines. A report covering Basic Rules and Pole Tables for construction and maintenance of wood pole lines along railroads for telegraph and telephone lines was presented at the annual meeting of the Telegraph and Telephone Section of the American Railway Association in September, 1921.

Your Committee issued questionnaires to about twenty representative railroads requesting information regarding railroad transmission and distribution lines at present in operation. The response to those questionnaires was not very satisfactory, but some data of interest has been collected and tabulated for the information of the Association.

The subject of transmission line standards is extremely active just now. Specifications have been issued or are being considered by several state Public Utilities Commissions, and by various technical organizations. Unfortunately, however, it is not assured that these various efforts will be properly coördinated or based on a complete view of the situation.

The establishment of common standards for power work and a reduction in the present number of types and kinds of line construction material is very desirable from an economic standpoint, and your Committee hopes to coöperate with other bodies to promote this result.

The National Electrical Safety Code, while not providing actual specifications, nevertheless contains much data which will be of value in preparing standards.

The National Electric Light Association has this year issued a very able report on transmission line construction. In that report is presented a great deal of data collected as information from member companies, regarding practices in present use.

The distinction between "transmission" and "distribution" lines is not a sharp one, in fact, the characteristics often overlap. The structural problems are practically the same in both instances. A true transmission line is generally a trunk line transmitting large amounts of power over long distances at high voltage, while the distribution line transmits generally smaller amounts of power over shorter distances and at lower voltages.

By far the greatest experience and development in transmission and distribution line construction has been that of the electric power companies. It seems probable that types of good construction which have proved satisfactory for them may be adequate for lines of a similar class for railroad use. However, the proximity to railroad tracks presents hazard to trains from pole and wire failures which is an important consideration. The most important difference would probably be that railroad lines are usually confined to restricted right-of-way. The railroads may properly take advantage of a cleared private right-of-way by adopting smaller overhead clearance. Railroad engineers must often adopt types of construction adapted to growth on a single line, whereas power companies may frequently develop with advantage through loops or alternative routes.

A particularly unfavorable location for an outside line from the railroad point of view is that parallel to the right-of-way and immediately outside the property line. Many instances of this sort exist and in some cases there is serious conflict between such outside lines and the low voltage circuits of the railroad.

Recommendations

The Committee recommends that the subject be continued with a view of submitting next year Standard Transmission Line Specifications for the approval of the Association.

Appendix F

ITEM (7) CLEARANCES—THIRD RAIL AND OVERHEAD

H. M. Bassett, *Chairman;*
A. E. Owen, *Vice-Chairman;*
H. K. Lowry,
E. J. Correll,
F. D. Hall,
Sub-Committee.

The Committee communicated with an official of each electrified steam railroad; has revised the record tables and brought them up to date as shown on Statement 1, page 1, Data Regarding Third Rail Clearances, and on Statement 2, pages 1 to 6, inclusive, Data Regarding Overhead Clearances.

The Committee recommends that these tables be accepted as information and published in the Proceedings.

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

Statement 1
Page 1

Data Regarding Third Rail Clearances.

Name of Company	Top or Under Contact	Protected	Uses Steam Equipment	Structures Clear Prop Lines	Mileage in Operation	Mileage Planned for Immediate Future	Mileage Using Steam Equipment	Remarks
Albany Southern R R Co	Top	No	No	Yes	53 50	None	None	1 Mile O H trolley included in total
Aurora Elgin & Chicago	"	"	Yes	No	98.68	"	98 68	
Baltimore & Ohio System	"	Partly	"		7 96	"	7.96	Rail completely protected at Stations & partially protected at all other points by guard boards 1" above head of Rail
Boston Elevated Ry	"	No	No		43 161	2 Miles	None	Partially protected
Brooklyn Rapid Transit	"	About 40%	"		254 978	15½ "	"	
Central California Traction Co.	Under	Yes	Emergency Only	Yes	70.00	None	"	24 miles O H Trolley included in Total
Detroit River Tunnel Co.	"	"	Yes	"	26 43	"	26 43	2 7 miles O H Trolley included in Total
Grand Rapids, Grand Haven & Muskegon R.R.	Top	No	No		46 00	"	None	10 " " " " " "
Hudson & Manhattan R R Co	"	Yes	"	No	20.00	"	"	Subway
Interborough Rapid Transit Co.	"	"	"	"	373.15	1.34	"	
Lackawanna & Wyoming Valley	"	No	Yes	"	52 00	None	52 00	10 Miles O H Trolley included in total
Long Island R. R Co.	"	Yes	"		225.65	"	225 65	
Metropolitan West Side, Chicago	"	No	No	"	163.10	"	10.00	16 Miles O.H Sliding Contact
Michigan Ry Co.	"	"	Yes		224.00	"	None	O.H & underground conductors at Xings only
New York Central R R Co	Under	Yes	"	Yes	268.3		268.3	2 22 Miles O H Conductors
New York State Rys.	"	"	"		105 38	None	103 18	
Northwestern Pacific R R Co.	Top	Stas only	"		35.5		35.5	
Philadelphia & Western R R Co.	Top	Yes	No	No	37 15	None	None	9 m O.H T Yards and Sidings not in total
Pennsylvania R.R. New York Div.	"	"	Yes	Yes	110.8	"	22 70	1 18 m O H contact excluded in total
Penn'a. R.R. West Jersey & Seashore	"	"	"		150.30		150.30	8 61 m O H trolley included in total
Philadelphia Rapid Transit Co	Under	"	No	No	19.33	None	None	Subway & Elevated Lines
Puget Sound Electric Ry	Top	No	"	"	69 69	"	"	27 65 Miles O H Trolley included in total
Sacramento Northern R.R. (Formerly Northern Electric R.R.)	"	Sta. ground only	Emergency only	"	215 72	"	"	52.79 m. " " " " "
Scioto Valley Traction Co	"	No	No		75.11	"	"	6.81 m. trolley " " "
Wilkes-Barre & Hazelton Ry. Co	"	Yes	"	Slight	30.74	"	"	1.54 - O.H. - not in total, on Lehigh Tract. Co.

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Data Regarding Overhead Clearance.

Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction of Xings, other Roads	Remarks
Bangor Ry & Elect. Co.	2/0 8 and 0	Maximum 23'-0" Standard 19'-0" Minimum 15'-0"	65.67 Mi.	None	None Submitted	D.C.-600	Trolley		
Boston & Maine R.R.	4/0 Grooved	Standard 22'-0" Minimum 15'-10"	21.31 Mi.	21.31 Mi.	Submitted	Single Phase A.C. 11,000	Pantagraph	Print Submitted	Berkshire St Ry. at North Adams 20'-0" 15'-10" Standard for Hoosac Tunnel
British Columbia Elect Ry. Co	4/0 Grooved & Round	22'-6"	183 Mi. Interb 185 M. City	None		D.C. 550-600	Trolley	None	Steam Road Equipment handled in daily interchange of Freight. Freight handled by Electric Locomotives
Brooklyn Rapid Transit	Round 1/0-2/0-3/0 4/0	Maximum 21'-6" Standard 18'-0" Minimum 12'-0"	554.023 Mi.	See Note	Outline of Equipment	D.C. 575	Trolley	None	Freight handled by Electric Locomotive
Butte, Anaconda & Pacific Ry. Co.	4/0 Grooved	Maximum 22'-0" Standard 22'-0"	122.30 Mi.	42 Mi.	None Submitted	D.C. 2400 Approx. 1000 Amp	Pantagraph		
Cedar Rapids and Iowa City Ry.	4/0	Maximum 22'-0" Average 19'-0"	45.7 Miles	5 Miles	Submitted	D.C. 600	Trolley	Yes	Main Line only
Central New York Southern R.R.	4/0 Grooved	19'-0"	6 Miles	None	Submitted	D.C. 600	Trolley	None	Do not Cross any other R.R.
Chautauqua Traction Co.	2/0	16'-0"	28 Miles	None	None Submitted	D.C. 600	Trolley	Overhead Xings	Steam Road Equipment handled in daily interchange of Freight. Freight handled by Electric Locomotives.
Chicago, Lake Shore & South Bend Ry. Co.	4/0 Grooved	Maximum 22'-6" Standard 21'-0" Minimum 15'-6	105.1 Miles	105.1 Miles	Submitted	Single Phase A.C. 6,600	Pantagraph	None	Freight handled by 2 Electric Locomotives
Chicago, Milwaukee & St. Paul Ry. Co.	4/0 Grooved	Standard 24'-2"	649 Miles	None	None Submitted	D.C. 3000	Pantagraph		
Chicago, North Shore & Milwaukee R.R.	3/0 Grooved	Maximum 22'-6" Standard 22'-0" Minimum 14'-9"	182.65 Miles	A few Freight Cars	None Submitted	D.C. 600	Trolley	Catenary	
Chicago, Ottawa & Peoria Ry	3/0 8&0 [illegible]oved	Maximum 22'-6" Average 18'-0"	106.56 Miles	None	Submitted	D.C. 650	Trolley	Yes	Steam Road Equipment handled in daily interchange of Freight
Cincinnati, Georgetown & Portsmouth R.R.	3/0 & 4/0 Grooved	Maximum 22'-0" Average 19'-0"	62 Miles	None	None Submitted	D.C. 600	Trolley	None	Freight Equipment interchanged
Clinton, Davenport & Muscatine Ry. Co.	3/0 & 4/0 Round	No Standards in State	66 Miles	None	None Submitted	D.C. 600-1200	Trolley	Double Spans, all poles heavy and back guys	Catenary Construction 25 mi.
Detroit United Ry.	2/0 3/0 Grooved Round & 8	Maximum 22'-6" Standard 18'-6" Minimum 14'-6"	902.12 Mi.	116.9 Mi.	Std. Line Construction	D.C.-600	Trolley	Built according to Specifications of Michigan Ry. Comm.	

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Data Regarding Overhead Clearance.

Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction of Xings other Roads	Remarks
Erie Railroad Co.	3/0 Grooved	Maximum 24'-0" Standard 22'-0" Minimum 16'-0"	38 Miles	34 Miles	None Submitted	11,000	Pantagraph	None	Operates Std. Steam engines for Freight.
Evansville, Suburban & Newburg Ry. Co.	3/0 Grooved	Maximum 22'-0" Average 18'-0"	25 Miles	25 Miles	None Submitted	D.C. 600	Trolley	None	Operates Std. Steam engines for Freight
Fonda, Johnstown & Gloversville R.R. Co.	4/0 Grooved	Max 22'-0 Steam Xings Standard 18'-0" Minimum 15'-0"	74 Miles	1/2 Mile	None Submitted	D.C. 600	Trolley	None	
Fort Dodge, Des Moines & Southern R.R. Co.	3/0 - 4/0 Grooved	Maximum 24'-0" Standard 23'-0" Minimum 21'-0"	150 Miles	150 Miles	None Submitted	D.C. 1200	Trolley	None	Handle Std. Freight Cars with Elec. Locomotives
Galveston Electric Co.	2/0 Round	Maximum 22'-0" Standard 18'-0" Minimum 17'-0"	38.43 Mi.	None	None Submitted	D.C. 600	Trolley		
Grand River Railway (formerly Galt, Preston & Hespeler Ry.)	3/0	Maximum 22'-6" Average 18'-6"	22 Miles	1/2 Mile	None Submitted	D.C. 1500	Trolley	None	Std. Freight & Pass. Equip. handled with Electric locomotive & occasionally by steam
Grand Trunk Ry. System (St. Clair Tunnel)	4/0 & 300,000 C.M. Grooved	Maximum 22' in Yds. 16'-6 in Tunnel Minimum 15'-4" " "	12 Miles	About 10 Miles	Submitted	Single Phase A.C. 3300	Pantagraph	None	
Great Northern Ry. Co. (Cascade Tunnel)	2-4/0 Grooved 1" C to C	Maximum 22'-6" in Yds. Minimum 17'-4 in Tunnel 8' C to C	8.5 Miles	8.5 Miles	Submitted	Three Phase A.C. 6600 V 25 Cyc.	Trolley	None	3.8 miles Side Track included in 8.5 Elect. Track
Illinois Traction System	3/0 Grooved	Maximum 23'-0" Standard 13'-0" Minimum 18'-0"	510.8 Miles	510.8 Miles	None Submitted	D.C. 600	Trolley	As per State Comm. rules for height only	Handles Std. Cars but no locomotives
Indianapolis & Louisville Traction Ry. Co.	4/0 Grooved	Maximum 21'-0" Average 18'-0"	40.92 Miles	None	None Submitted	D.C. 600	Trolley	Elevated Trolley wires to Clear legal requirements	Exchange Equip. (Pass & Freight) with Interstate Public Service Co.
Joplin & Pittsburg Ry. Co.	4/0-0-8 2/0-0	Maximum 22'-0" Average 19'-0"	104 Miles	None	None Submitted	D.C. 600	Trolley	Wire Clearance 22'-0"	Never operated with Steam
Kansas City, Clay County, & St. Joseph Ry. Co.	4/0 Grooved	Maximum 23'-0" Average 19'-0"	70 Miles	See Note	None Submitted	D.C. 1400	Trolley		Freight Equipment Interchanged
Lake Erie & Northern	4/0 Grooved	Maximum 22'-6" Standard 21'-6" Minimum 16'-6"	55.1 Miles	55.1 Miles	Submitted	D.C. 1500	Trolley & Pantagraph		Std. Freight & Pass. Equip. handled with Electric Locomotive & occasionally by steam
Lake Shore Electric Ry. Co.	4/0 Grooved	Maximum 22'-0" Standard 18'-0" Minimum 14'-6"	218 Miles	Practically all from outside connections	All New Work	D.C. 650 (Trolley) 18000 (Trans.)	Trolley	None	
Lehigh Valley Transit Co.	2/0 - 4/0 Round & 8	Standard 18'-0"	208 Miles	None	None Submitted	D.C. 600	Trolley		

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Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip. Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction of X-ings other Roads.	Remarks
London & Port Stanley Ry. Co.	4/0 Catenary	23'-2"	24.6 Mi.	24.6 Mi.	None Submitted	D.C. 1500	Pantagraph	Yes	
Louisville & Northern Railway & Lighting Co. Now Interstate Public Service Co.	3/0 Grooved	Maximum 22'-0" Average 20'-0"	20.74 Miles	None	None Submitted	D.C. 600	Trolley	Yes	Mileage includes Louisville Bridge & 1.89 Miles of Louisville Ry.
Mason City & Clear Lake R.R. Co.	2/0 Round	Maximum 23'-0" Minimum 21'-0"	20.6 Miles	None	None Submitted	D.C. 650	Trolley	None	Interchange Freight Equip. with Steam Roads
Minneapolis, Anoka & Cuyuna Range Ry. Co.	4/0	Maximum 22'-0" Average 16'-0"	19.21 Miles	None	None Submitted	D.C. 650	Trolley {Shoe / Wheel}	Yes	
Montreal & Southern Counties Ry. Co.	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 15'-0"	57.5 Miles	25.2 Miles	None Submitted	D.C. 600	Trolley	None	
Mt. Royal Tunnel & Terminal Ry. (Canadian National Rys.)	4/0 Catenary		10 Miles	10 Miles		D.C. 2400	Pantagraph		
Niagara, St. Catharines & Toronto (Canadian National Rys.)	4/0 Grooved	Average 22'-6" Minimum 19'-0"	76 Miles	63.5 Miles		D.C. 600	Trolley		12.5 Mi. of Sidings & Spurs included in 72 mi. of Elec. Track
New York Central R.R. Co. (Overhead)	8 & I	So. 144 St. Max. 15'-3" Min. 15'-1" No. 144 St. Max. 15'-5" Min. 15'-3	2.22 Miles	.071 Mi.		D.C. 660	Shoe	None	Running Position 15'-1" Low 14'-7⅞" to 14'-9½" (N.Y.C.) High 15'-5⅜" to 15'-6"
N.Y.N.H. & H.R.R. Co. (MAIN LINE)	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 15'-6"	344.6* Miles	344.6* Miles	Submitted	A.C. 11,000	Pantagraph	Yes	*Includes 11.6 miles on the New York Connecting R.R.
N.Y.N.H. & H.R.R. Co. (N.Y.W. & B.)	4/0 8	16'-5"	71.66 Miles	None	Submitted	A.C. 11,000	Pantagraph	Yes	
New York State Railways	2/0 3/0 4/0	Maximum 22'-0" Standard 20'-0"	502.41 Mi.	None	Submitted	D.C. 650	Trolley	None	22' Std. on Elec. Steam roads and R.R. Crossings - 20' Std. on Trolley or City Lines
Norfolk Southern R.R. Co.	4/0 Grooved	Maximum 21'-0" Standard 21'-0" Minimum 19'-4"	65.818 Miles	65.818 Miles	Submitted	D.C. 550 A.C. 13,200 (25 Cycle)	Trolley		Mileage includes 21.684 Mi. of Sidings.
Norfolk & Western Ry. Co.	4/0 Grooved	Standard 24'-0" Minimum 23'-9"	106 Miles	106 Miles	Submitted	Trans. 44,000 Line 11,000	Pantagraph	Foreign Lines are required to cross, using Steel Poles and giving 50' Clear Height above	Rail
Northern Electric Railway Now Sacramento Northern R.R.	4/0 - 2/0	22'-0"	52.79 Miles	None	Submitted	D.C. 600	Trolley		
Northern Ohio Traction & Light Co.	4/0 Grooved	Max. 22'-0" at R.R. X-ings Standard 18'-0"	242.2 Miles	None	None Submitted	D.C. 600	Trolley		
Northern Texas Traction Co.	2/0-3/0-4/0	Maximum 23'-0" Average 19'-0"	138.17 Miles	None	None Submitted	D.C. 600	Trolley	None	

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Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction of Xings other Roads	Remarks
Oakland, Antioch & Eastern R.R. Now San Francisco-Sacramento R.R.	4/0 Grooved	Maximum 22'-0" Standard 20'-0" Minimum 19'-0"	113 Miles	None	Submitted	D.C. 1200	Trolley	None	Height of Trolley now 22' Minimum in this State for all new construction
Ohio Electric Ry. Co. *(Indiana, Columbus & Eastern Trac. Co. (Columbus, Newark & Zanesville El. Ry. Co. *Formerly Ohio Electric Rys. Co.	4/0 Grooved & Round	Maximum 22'-0" Standard 21'-0" Minimum 16'-0"	82.91 Miles 257.20 " 95.85 "	None 40 Miles None	See Note	D.C. 600 to 650	Trolley	A.E.R.E. Assn.	Pole line 8' from ¢ of track. Bigs. 10'.
Oregon Electric Ry.	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 16'-0"	195.91 Miles	None	None Submitted	D.C. 10 Miles 600 185.91 1500	Trolley	Yes	
Pacific Electric Ry. Co.	3/0 4/0 Grooved	Maximum 22'-0" Minimum 19'-0"	1104.478 Mi.	18.66 Miles	Submitted	D.C. 600 & 1200	Trolley	Insulated Crossings	
Pacific Northwest Traction Co.	2/0 & 4/0 Round 00 Grooved 0000	Maximum 21'-0" Standard 20'-0" Minimum 19'-0"	61.42 Mi.	61.42 Mi.	Submitted	D.C. 600	Trolley	23' Clearance over Steam Lines	Includes Northern & Southern Divisions
Pennsylvania R.R. Co. (New York Div.)	25 lb. Rail "T" Shape	Maximum 15'-5" Standard 15'-4" Minimum 15'-2"	1.18 Miles	None	Submitted	D.C. 650	Pantograph	None	
Pennsylvania R.R. Co. (Philadelphia, Paoli & Chestnut Hill Divs.)	3/0 Grooved	Maximum 22'-0" Standard 22'-0" Minimum 15'-8½"	119.49 Mi.	119.49 Mi.	Submitted	Single Phase A.C. 11,000	Pantograph	None	
Pennsylvania R.R. Co. (West Jersey & Seashore)	4/0 Grooved	Maximum 22'-0" Standard 22'-0" Minimum 17'-2"	86.1 Miles	86.1 Miles	Submitted	D.C. 675	Trolley	None	
Portland Railway Light & Power Co.	1/0-3/0-4/0 Grooved & 8.0	City: Max 21'-0", Avg 19'-0" Interurban: 22'-0", 21'-0"	308.731 Mi.	None	Submitted	D.C. 600	Trolley	Insulated Crossings	186.[illegible] mi City Lines Owned 10.541 " " Oper not " 0.94 " Partly " 111.497 Interurban Lines owned
Puget Sound Electric Railway	4/0 Grooved	Maximum 22'-0" Average 19'-0"	69.69 Mi.	None	Submitted	D.C. 600	Trolley	Trolley Height 22'-0"	
Quebec Railway Light Heat & Power Co.	2/0 Round	Standard 21'-0"	46.89 Mi.	46.89 Mi.	None Submitted	D.C. 550	Trolley	Built According to Specifications of Canadian Ry. Commission	
Rock Island Southern Ry. (Now Galesburg & Western R.R.)	3/0 8& Grooved	Maximum 22'-0"	15 Miles	None	None Submitted	D.C. 600	Trolley	None	
Salt Lake & Utah R.R. Co.	4/0 Grooved	Maximum 23'-0" Standard 22'-0" Minimum 18'-0"	92 Miles	None	Submitted	D.C. 1500	Trolley	In accordance with General Order No. 10 Public Utilities Comm. of Idaho	
San Francisco, Napa & Calistoga Ry.	3/0 Grooved	19'-0" New Construct 22'	45.31 Miles	7 Miles	Submitted	A.C. 3300	Pantograph	Gen. Order 26 C.S.R.C.	22' Trolley Clearance on Reconstruction or New Work
Southern Illinois Ry. & Power Co.	4/0 Grooved	Maximum 22'-0" Average 18'-0"	15.13 Miles	All Freight	None Submitted	D.C. 1200	Trolley	None	

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Southern New York Power & Ry Corporation	2/0	Average 18'0"	68 Miles	None	None Submitted	D.C. 600	Trolley	Yes	
Southern Pacific Co. [Oakland Alameda & Berkeley]	4/0 Grooved	Maximum 22'0" Standard 22'0" Minimum 17'6"	*121.54 Mi.	†22.30 Mi.	None Submitted	D.C. 1200	Pantagraph	Double Insulation with grounded Section	*Includes 20 mi of Sidings †Includes 10 mi. Sidings & Spurs
Southern Pacific Co [Portland Div]	4/0 Grooved	Average 22'0"	*187.22 Mi + 37.77 Mi St Car lines	†155.94 Mi.	Submitted	D.C. 1600	Pantagraph	Double Insulation with ungrounded dead Section	*33 Mi. Sidings & Spurs. †8.18 Mi. Sidings & Spurs
Spokane & East. Ry. & Pow. Co. Inland Empire Railroad	3/0-4/0 8 & Grooved	Maximum 22'0" Average 19'0"	184.4 Miles	None	None Submitted	A.C. 6600 → D.C. 600 →	Pantagraph Trolley	None	
Tacoma Ry & Power Co.	2/0 Round	Maximum 22'0" Average 19'0"	115.96 Mi.	None	None Submitted	D.C. 600	Trolley	Trolley height 22'0"	Includes Pacific Traction Co.
Tarrant County Traction Co.	4/0 Grooved	Maximum 23'0" Standard 19'0" Minimum 17'0"	29.97 Mi.	None	None Submitted	D.C. 600	Trolley	National Trolley Guard	
Texas Electric Ry.	4/0 Grooved	Maximum 23'0" Standard 19'0" Minimum 17'0"	229.94 Mi.	None	None Submitted	D.C. 600 & 1200	Trolley	National Trolley Guards	
Toledo & Western R.R. Co.	4/0 8	Maximum 21'0" Standard 18'0" Minimum 18'0"	85.6 Miles	85.6 Miles	None Submitted	D.C. 600	Trolley	Basket the line, also towers over foreign lines	
Toronto Suburban Ry. [Canadian National Ry's]	4/0 Catenary & 2/0	Average 20'0" Minimum 13'6"	64.12 Mi.	46.5 Mi		D.C. 600 A.C. 1500	Trolley		Sidings Wyes, etc 4.7 Mi.
Twin City Lines Minneapolis Minn	2/0 8	Maximum 22'6" Standard 18'0" Minimum 17'0"	9.0 Mi.	None	None Submitted	D.C. 600	Trolley	22'0" trolley above Steam Road tracks	
Union Traction Co. of Indiana	1/0-2/0-3/0 Round, 8 & Grooved	Maximum 22'0" Standard 18' to 20' Min 15'0" to Bridges	408 Mi. Inter 45 Mi. City	1 Mile	Submitted	D.C. 600 to 650	Trolley	None	
United Elec. Ry's Co. formerly Rhode Island Co.	2/0-4/0 Round & Grooved	Max. 22'0" at R.R. Xings Standard 19' to 20' Min 13'0" under Br	331.165 Mi.	None	None Submitted	D.C. 600	Trolley	Double Span-One each Side of Crossings	
United Railways Co.	4/0 Grooved	Maximum 23'0" Standard 22'0" Minimum 16'0"	28.1 Mi.		None Submitted	D.C. 600-8.7 mi D.C. 1200-19.4 mi	Trolley	Limited Insulation	
Utah Idaho Central R.R. Co.	2/0-4/0 Grooved	Interurban 22'6"	129. Mi.	None	As per Railway Line clearance guide	D.C. 750 to 1500	Trolley	Yes	Interurban Lines
Utah Rapid Transit Co.	2/0-4/0 Grooved	18'0" except at Crossings then 20'0"	28. Mi.	None		D.C. 600	Trolley	Trolley height 20'0"	City Lines
Visalia Electric R.R.	3/0	22'0"	48.68 Mi	16.64 Mi	None Submitted	A.C. 3300	Pantagraph	None	Interchange Equipment with Steam Line.

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Name of Company	Conductor	Height Above Rail	Electrified Single Track	Steam Equip Handled	Clearance Diagram	Current & Voltage	Contact Device	Special Construction of Xings other Roads	Remarks
Walla Walla Valley R'y Co.	4/0	21'-0"	27.74 Miles	14 Miles	None Submitted	D.C. 575	Trolley		
Washington Baltimore & Annapolis Elec R R Co.	4/0 Grooved	Maximum 21'-0" Standard 19'-0" Minimum 15'-0"	137.10 Mi.	40 Miles	None Submitted	D.C. 1200	Trolley	None	
Washington & Old Dominion R'y	4/0 Grooved	22'-0"	88.3 Miles	53.5 Miles	None Submitted	D.C. 650 A.C. 33,000	Trolley	None	
Waterloo, Cedar Falls & Northern R'y Co.	4/0 Grooved 2/0 Round	City / Interurban Max. 22'-0" / 23'-0" Stand 18'-6" / 21'-0" Min. 16'-0" / 18'-6"	135.77 Miles	115.72 Miles	None Submitted	D.C. 650 & 1300	Trolley	A.E.R.E.A. Standard Specifications	
Western New York & Penna. Traction Co.	4/0	Maximum 22'-0" Minimum 18'-0"	99 Miles	None	None Submitted	D.C. 600	Trolley	None	Interchange Freight equip with 4 Steam Rds
Western Ohio R'y Co	2/0 Round	Maximum 22'-0" Minimum 18'-0"	112 Miles	None	None Submitted	D.C. 650	Trolley	None	
Youngstown & Southern Ry. Co.	3/0 Grooved	Standard 18'-0"	20 Miles	None	None Submitted	D.C. 625	Trolley	None	

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Appendix G

ITEM (8) COLLABORATION WITH COMMITTEE XVI—ECONOMICS OF RAILWAY LOCATION

D. J. Brumley, *Chairman;*
W. L. Morse, *Vice-Chairman;*
R. Beeuwkes,
J. V. Duer,
J. C. Davidson,
S. Withington,
Sub-Committee.

The Committee was directed to collaborate with the Committee on Economics of Railway Location as affected by the introduction of electric locomotives, because of the comparison of steam and electric operation made by Committee XVI in its report presented at the last Convention. Although we have offered our services and they have been willingly accepted, no opportunity to effectively coöperate has been afforded, up to the time of submitting this report.

Because of the importance of the subject, it is recommended that collaboration with the Committee on Economics of Railway Location be continued.

Appendix H

ITEM (10) STANDARDIZATION

H. K. Lowry, *Chairman;*
S. Withington, *Vice-Chairman;*
M. Schreiber,
J. C. Davidson,
L. S. Wells,
Sub-Committee.

The Committee on Standardization submitted to the Committee the standardization of one or more of the following articles:

(a) Insulators.
(b) Friction, rubber and other tapes.
(c) Knife and snap switches.

The Committee elected this year to report on friction and other tapes.

After the review of the more general specifications for tapes, and considering the late activity of the American Society for Testing Materials, resulting in completion of tentative specifications for these tapes, the Committee was inclined to advance them for recommended adoption by the A.R.E.A., if upon review they could be found satisfactory for its work. Especially did the Committee have in mind the general policy of adoption, when practicable, of specifications prepared by societies, specialists in their line, rather than devise new specifications, the reasons for which are obvious.

The specifications presented are the result of review of the A.S.T.M. specifications, somewhat modified but agreeable in such form, to the committee of the A.S.T.M. and to be by them in that form adopted. It is pointed out that the A.S.T.M. proposes these specifications as tentative, which is their practice with regard to all specifications for the first year after adoption.

Recommendations

It is the recommendation of your Committee that these specifications be adopted as recommended practice and printed in the Manual.

RAILROAD SPECIFICATIONS FOR COMMERCIAL ADHESIVE TAPE FOR ELECTRICAL PURPOSES

Material Covered

1. These specifications cover adhesive tape (also called "friction" tape), consisting of strips of cotton sheeting impregnated with an adhesive insulating compound. The tape is largely used to cover electrical insulation applied to wires and cables.

(I) Manufacture

Cotton Sheeting

2. The cotton sheeting layer shall be made from a sheeting evenly and firmly woven from good cotton and as free from unsightly defects, dirt, knots, lumps and irregularities of twist as is consistent with the best manufacturing practice. The threads shall run in as straight lines as possible without waving, so as to reduce to a minimum the raveling of the cloth when cut into tape.

Frictioning Compound

3. The frictioning compound shall be an adhesive and insulating compound practically free from free sulphur or other substances which would have a deteriorating effect on copper or other metals or on the fabric.

Impregnation of Fabric

4. The fabric shall be thoroughly impregnated and evenly covered on both sides with the frictioning compound.

Adhesiveness of Compound

5. The compound shall adhere firmly to the fabric and shall not pull away from the fabric so as to leave bare spots when adjacent layers of the tape are separated.

(II) Chemical Properties

Sulphur

6. The compound shall contain not more than 0.05 per cent of free sulphur.

Discoloration of Copper

7. When wrapped on a clean, bright, smooth copper red and baked at 100 deg. Centigrade (212 deg. Fahr.) for 16 hours, the compound shall not discolor the copper.

(III) Physical Properties and Tests

Pin Holes

8. When the tape is held before a strong light, the number of pin holes shall be determined in a length of not less than 3 yards. The

number of pin holes shall not exceed the limits given in the following table:

Width, inches.	Maximum number in 3 yd.	Maximum number in any single yd.
½	6	3
¾	6	3
1	9	4
1½	12	5
2	15	6

Tensile Strength

9. The tensile strength of the tape shall be not less than 40 lb. per inch of width. The initial distance between the jaws of the testing machine shall be 12 inches and the rate of separation of the jaws shall be 20 inches per minute.

Friction

10. (a) The adhesion between adjacent layers of the tape shall be such that when a strip of tape 2 feet long is taken from a roll and wound upon a mandrel 1 in. in diameter under a tension of 10 lb. per inch of width at a rate of 30 inches per minute, a weight of 4 lb. per inch of width shall not cause the plies to separate at a rate greater than 30 inches per minute.

(b) After a strip has been exposed to dry air at a temperature of 100 degrees Centigrade (212 deg. Fahr.) for 16 hours and then cooled to room temperature, a test specimen shall withstand the test prescribed in paragraph (a) except that the weight applied to unwind the tape shall be 1⅓ lb. per inch of width instead of 4 lb.

(c) The tests shall be made in a room temperature not lower than 18 deg. Centigrade (65 deg. Fahr.) nor higher than 32 deg. Centigrade (90 deg. Fahr.) and the sample shall have been kept within those temperature limits 30 minutes previous to the time of testing.

Dielectric Strength

11. The test for dielectric strength shall be made as follows: The tape shall be spirally wound with one-third lap on a smooth metal rod, one inch in diameter, for a distance of six inches. Two inches in the center shall be covered with metal foil and securely bound with tape. The tape shall withstand without puncture for a period of 5 minutes, the application of 1,000 volts (r.m.s. value) at a frequency not exceeding 65 cycles per second applied to the metal rod and metal foil.

Test Samples

12. One roll from each 250 rolls shall be taken at random for test. At least two feet of the outer layers shall be removed and discarded before taking specimens for test.

(IV) Standard Weight, Dimensions and Variations

Weights, Dimensions and Yardage

13. The tape shall conform to the following requirements:

Width in.	Thickness in.	Nominal weight per roll lb.	Minimum net weight per 100 rolls lb. (a)	Minimum length per pound yd. (a)
½	0.015	¼	25	82
¾	0.015	½	50	55
1	0.015	½	50	41
1½	0.015	1 or 1¼	100 or 125	27
2	0.015	1½	150	20

(a) Exclusive of core, wrapping and box.

Measurement of Thickness

14. The thickness shall be measured with a micrometer graduated to 0.001 inches, having a circular foot, 0.24 to 0.26 inches in diameter and with a pressure on the specimen of not less than 8 ounces nor more than 10 ounces. Four measurements shall be taken at random in a length of not less than 3 feet and no result shall be outside the limits prescribed.

Permissible Variations

15. The width shall not vary from the specified value by more than $\frac{1}{32}$-inch. The thickness shall not vary from the specified value by more than 0.002 inch.

(V) Packing and Marking

Packing

16. Each roll shall be wrapped in paraffined paper or metal foil and enclosed in a suitable box. The wrapping shall be secure and shall thoroughly protect the contents.

Marking

17. Each box shall be marked with the name of the manufacturer or a trade mark together with the nominal width and weight of the tape.

(VI) Inspection and Rejection

Time of Inspection

18. The tape shall be inspected and tested within four weeks from the date of delivery.

Retests and Rejections

19. If the tape fails in any one test of those prescribed in these specifications, two additional specimens shall be taken and submitted to that test. If either of these two additional specimens fails, the lot of tape represented by that sample shall be rejected.

RAILROAD SPECIFICATIONS FOR RUBBER INSULATING TAPE

Material Covered

1. These specifications cover rubber insulating tape to be used for insulating joints in electric wires and cables.

(I) MANUFACTURE

Compound

2. The tape shall be a rubber compound which shall be well, evenly and smoothly calendered in sheets, then wound tightly on a mandrel with a separator interposed between adjacent layers and cut into rolls of uniform width.

Separator

3. The separator shall be of glazed cotton or linen cloth or a parchment paper and shall be attached to and cover the outer side of the tape. When unwound from the original roll it shall show no undue tendency to stick to the rubber.

(II) CHEMICAL PROPERTIES AND TESTS

Composition

4. The tape shall be a rubber compound containing not less than 30 per cent. of the best quality Hevea rubber, not more than one per cent. of free sulphur and not more than 4 per cent. of waxy hydrocarbons.

The remainder shall consist only of suitable dry inorganic mineral fillers. The compound shall contain no reclaimed rubber, substitutes or organic matter other than herein above specified. All percentages shall be based on the weight of the original compound.

Chemical Analysis

5. If an analysis of the compound is made, it shall be carried out in accordance with the Joint Rubber Insulation Committee's procedure.

(III) PHYSICAL PROPERTIES AND TESTS

Tensile Strength

6. (a) The tensile strength of the tape shall be not less than 300 lb. per sq. in.

(b) The tests shall be made with a power driven, pendulum-type tension testing machine; the initial distance between the jaws shall be 3 in. and the rate of separation of the jaws shall be 20 in. per minute. The width of the test specimen shall be 0.5 in.

(c) Three specimens of each sample free from visible flaws shall be tested. The average result shall be taken as the tensile strength.

(d) The temperature of the room shall be not lower than 18 deg. Centigrade (65 deg. Fahr.) nor higher than 32 deg. Centigrade (90 deg.

Fahr.) and the samples shall have been kept within these temperature limits for at least 30 minutes previous to the time of testing.

Dielectric Strength

7. Two brass ball sphere electrodes two cm. in diameter shall be brought so close together that the sample of tape can be just moved between them. The tape shall withstand without puncture for 5 minutes the application of an alternating potential of 10,000 volts (r.m.s. value) at a frequency not exceeding 65 cycles per second, applied to the spherical electrodes.

Fusion

8. The tape when wrapped to a thickness of ¼-in. and heated to a temperature of 65.5 deg. Centigrade (150 deg. Fahr.) for 20 minutes shall fuse into a homogeneous mass.

Test Samples

9. One roll for each 250 rolls shall be taken at random for test. At least 2 ft. of the outer layers shall be removed and discarded before taking specimens for test.

(IV) Standard Weights, Dimensions and Variations

Thickness, Weight and Yardage

10. The tape shall conform to the following requirements:

Width in.	Thickness in.	Nominal weight per roll lb.	Minimum net weight per 100 rolls lb. (a)	Minimum length per pound yd. (b)
½	0.035	½	50	22½
¾	0.035	½	50	15
1	0.035	1	100	11¼

(a) Exclusive of core, wrapping and box.

(b) Exclusive of core, wrapping, box and separator.

Permissible Variations

11. The width shall not vary from the specified value by more than 1/32-in. The thickness shall not vary from the specified value by more than 0.003 in.

Measurement Thickness

12. The thickness shall be measured with a micrometer graduated to 0.001 in. having a circular foot, 0.24 to 0.26-in. in diameter and with a pressure on the specimen of not less than 8 oz. or more than 10 oz. Four measurements shall be made at random in a length of not less than 3 ft. and no measurement shall be outside the limits prescribed in Sections 10 and 11.

(V) Packing and Marking

Packing

13. Each roll shall be wrapped in paraffined paper or metal foil and enclosed in a suitable box. The wrapping shall be secure and shall thoroughly protect the contents.

Marking

14. Each box shall be marked with the name of the manufacturer or trade mark and the nominal width and weight of the tape.

(VI) Inspection and Rejection

Time of Inspection

15. The tape shall be tested and inspected within four weeks of the date of delivery.

Retest and Rejection

16. If the tape fails in any one test of those prescribed in these specifications, two additional specimens shall be taken and submitted to that test. If either of these two additional specimens fails, the lot of tape represented by that sample roll shall be rejected.

REPORT OF COMMITTEE II—ON BALLAST

F. J. Stimson, *Chairman;*
C. W. Baldridge,
O. F. Barnes,
Theo. Bloecher, Jr.,
H. E. Boardman,
C. J. Coon,
C. E. Dare,
H. M. Doughty,
Paul Hamilton,
A. G. Holt,
G. H. Harris, *Vice-Chairman;*
F. A. Jones,
J. S. McBride,
H. L. Ripley,
F. R. Ramsey,
Hans Schantl,
M. A. Stainer,
Paul Sterling,
D. W. Thrower,
P. H. Winchester,
Lef Winship,

Committee.

To the American Railway Engineering Association:

Your Committee on Ballast reports on the following subjects:

1. Revision of the Manual

In Appendix "A" are given the proposed changes in the Manual.

2. Application of Ballast

In Appendix "B" the Committee submits data received from various railroad systems compiled as far as practicable in uniform statements; also diagrams showing proposed organization and distribution of men in a small emergency ballast raising gang: (1) for stone ballast; (2) for gravel ballast.

3. Ballast Tools

In Appendix "C" are given proposed specifications for track shovels and suggested plans for different types of shovel handles. There is shown also plan for "Spot Board."

4. Review of Previous Reports

The result of the study of this subject is given in Appendix "D."

CONCLUSIONS

1. The Committee recommends that there be added to the Manual the following definition:

Spot Board—A sighting board laid across the rails in advance of a raising gang to govern the amount of raise and insure uniform grade line.

2. The Committee recommends:

(a) That the diagrams in Appendix "B," showing the "Organization and Distribution of a Small Emergency Ballast Gang, *Stone Ballast,*" and the "Organization and Distribution of a Small Emergency Ballast Raising Gang, *Gravel* or *Cinders,*" be approved as recommended practice and printed in the Manual;

(b) That the matter in Appendix "B" referring to cost of ballast be accepted as information and the subject continued.

3. The Committee recommends:

(a) That the specifications for ballast shovels shown in Appendix "C" be approved as recommended practice and printed in the Manual.

(b) That the plans of track shovels as shown in Appendix "C" be accepted as suggestions for trial and that the subject of the design of track shovel be continued.

(c) That the plan of Spot Board as shown in Appendix "C" be approved as recommended practice and printed in the Manual.

4. The Committee recommends that for reasons given in Appendix "D" this subject be closed without further action.

Recommendations for Future Work

The Committee recommends that in addition to continuing subjects 2 and 3 the following subjects be added:

1. Revision with reference to size of stone of the Specifications for Stone Ballast.
2. Concrete foundations for crossings and tracks.
3. Mechanical tampers, with special reference to care and handling of machines.
4. Ballasting by contract.
5. Cross-section outline for gravel ballast roadbed.

Respectfully submitted,

THE COMMITTEE ON BALLAST,

F. J. STIMSON, *Chairman*.

Appendix A

ITEM 1—REVISION OF MANUAL

O. F. Barnes, *Chairman;*
Theodore Bloecher, Jr.,
H. E. Boardman,
C. J. Coon,
H. M. Doughty,
Sub-Committee.

The subject matter of the Manual was gone over carefully last year and a number of revisions submitted. The Committee, therefore, offers no revisions at this time.

However, inasmuch as the Manual does not contain a definition of a Spot Board, the following is submitted for inclusion:

"Spot Board—A sighting board laid across the rails in advance of a raising gang to govern the amount of raise and insure uniform grade line."

Appendix B

ITEM 2—APPLICATION OF BALLAST

C. W. Baldridge, *Chairman;*
F. R. Ramsey,
D. W. Thrower,
P. H. Winchester,
Lef Winship,
Sub-Committee.

The subject assigned to the Committee reads: "Make final report, if practicable, on time and cost studies covering the application of ballast, giving particular attention to the organization of the ballast gang and particular reference to the organization of small emergency ballast gangs."

Small Ballast Gangs

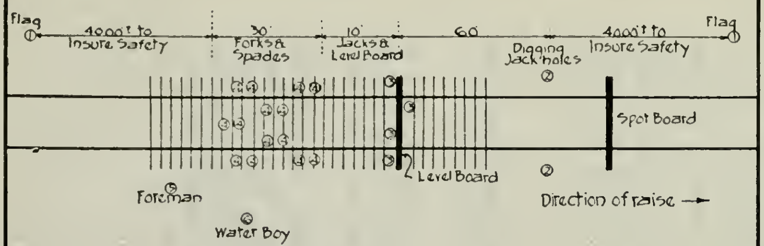
From time studies of raising track on ballast, both stone and gravel, which were made available by the Baltimore & Ohio Railroad, diagrams were prepared showing the organization and distribution of small ballast gangs for the two classes of ballast, stone and cinders or gravel. It is considered that so far as application is concerned cinders and gravel will require the same kind of gangs. The diagrams as presented are recommended for adoption as recommended practice.

Cost of Ballasting

A form which was prepared and sent out the early part of last year, asking for reports of the costs of ballasting in detail, brought replies from four railways.

The forms were made up under the letters A, B, C, D and E, form A being designed to show details of the cost of skeletonizing track preparatory to applying new ballast, cost to be shown in average time required to remove one cubic yard of old material.

Form B was designed to show the cost of unloading and spreading new ballast. The intent of the Committee was to have this cost reduced to cost per cubic yard basis, but this intent was evidently not made clear in the forms sent out, with the result that some of the replies showed the cost per car load and some by train load, of material handled and others by the amount of material used per mile.



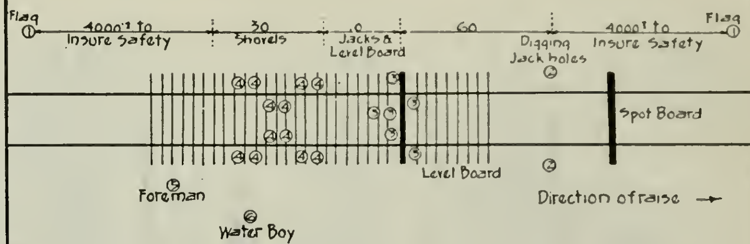
No	No of Men	Force
1	2	Flagmen
2	2	Dig Jackholes and handle spot board
3	4	Jackmen and handle level board
4	14	Tampers-Using forks inside and outside of rail working in pairs
5	1	Foreman
6	1	Water boy
		No of Men 20
		Total Force 24

TIME STUDY ON B&O R.R.

Schedule-Final raise of four to six inches when completely renewing ballast where track is tamped with forks in stone

Operation No.	OPERATION	Time Distribution Minutes Per Foot of One Track Stone
1	Running spot board	0.07
2	Digging Jack holes	0.71
3	Jacking up track	0.85
4	Running level board	0.20
5	Tamping	4.10
	Water boy	0.30
	Two flagmen	0.60
	Foreman (assume gang of twenty men)	0.30
	Total minutes for one foot of one track	7.13
	Standard Schedule. Hours per foot of one Track	.119
	Progress-180 ft per hour allowing 10% detention account of trains	

A.R.E.A.
Diagram Showing
Organization & Distribution
Of a Small
Emergency Ballast Raising Gang
STONE BALLAST
Nov 1921



No	No of Men	Force
1	2	Flagmen
2	2	Dig Jackholes and handle spot board
3	6	Jackmen and handle level board
4	12	Tampers-Using Shovels inside and outside of rail working in pairs.
5	1	Foreman
6	1	Water boy
		No. of Men 20
		Total Force 24

TIME STUDY ON B&O R.R

Schedule-Final raise of four to six inches when completely renewing ballast where track is tamped with shovels in gravel or cinder

Operation No.	OPERATION	Time Distribution Minutes Per Foot of One Track Gravel or Cinder
1	Running spot board	0.07
2	Digging Jack holes	0.35
3	Jacking up track	0.80
4	Running level board	0.18
5	Tamping	2.80
	Water boy	0.23
	Two flagmen	0.50
	Foreman (assume gang of twenty men)	0.25
	Total minutes for one foot of one track	5.18
	Standard Schedule, Hours per Foot of One Track	.086
	Progress-257 ft per hour allowing 10% detention account of trains	

A.R.E.A.
Diagram Showing
Organization & Distribution
Of a Small
Emergency Ballast Raising Gang
GRAVEL OR CINDER
Nov 1921

However, sufficient data was given in each case to permit of the costs given being worked into cost per car of material handled and cost per mile ballasted with reasonable accuracy.

Form C shows the cost of placing ballast, that is, the cost in man-hours, per linear foot of track, of raising the track and inserting the ballast under ties. Form D shows the cost, per linear foot of track, of dressing ballast.

Form E carries a recapitulation of the preceding forms and shows the entire cost of ballasting, per mile of track, expressed in payroll hours.

The Committee consider all figures supplied to them to be very creditable and would like to give credit to those who have gone to considerable trouble to aid the Committee and the Association in furnishing cost data, by publishing their names, but it seems to be customary not to do so, therefore the Committee bow to custom and designate the roads by arbitrary numbers assigned to identify the figures submitted by each.

In the tabulation shown below, the figures submitted by road No. 6 proved to be the cost of cleaning of stone ballast, and re-using the old stone with some additional new stone. The figures submitted by other roads, so far as could be determined, are for ballasting where the original material above the tie bed was discarded and new material supplied for the full lift which was given to the track.

Table No. I—A, B, C, D and E, give the figures taken from the reports which were returned in the form asked for by the Committee. Other reports which were not worked up in that form were received and are shown in the tables Nos. II, III, IV, V and VI. The costs shown in tables II, III and IV being shown in dollars and cents, while in tables V and VI the costs are shown in time.

Table I-A—Time Required and Cost of Skeletonizing Track per Cubic Yard of Material Removed

Railway	Single or Double Track	Kind of Material	Number of Men in Gang		Time Removing Material From		
			Foremen	Men	Crib	Center Ditch	Shoulder
6	Cleaning Double....	Stone......	1	13	70 min.	53 min.	53 min.
7	Ballasting Double....	Gravel....	1	11	25 min.	20 min.	18 min.
8	Ballasting Single.....	Dirt.......	2	13	49 min.	52 min.	6 min.

Depth Cut	Cu. Ft. Material Removed Per Foot of Track		No. Linear Ft. Track Per Yd. Material	Total Time Per Yd.	Time Lost	Cu. Yds. Per Mile	Total Time Per Ft.	Total Time Per Mile Hours
	Double	Single						
10 in.	23	....	2.5	176 min.	10%	....	....	9356
9 in.	11	....	2.45	63 min.	....	2155	....	5544
....	....	3.76	7.18	101 min.	....	735	....	1204

Table I-B—Time Required and Cost of Unloading Ballast per Car Load

Railway	Kind of Ballast	Kind of Car	Plow or Drag	Number of Men: Foremen	Number of Men: Men	Time: Placing Plow or Drag	Time: Releasing Bottoms
6 Cleaning Ballast..	Stone....	Hopper..	Drag...	1	17	5 min.	8.3 min.
7 Ballasting........	Stone....	Hopper	Drag....	1	10	4 min.	4 min.
8 Ballasting........	Gravel..	Rog. Bal	Tie-drag.	2	15	4 min.	1.5 min.
9 Ballasting........	Chats...	Rog. Bal	Tie-drag.	1	8	0.5 min.	6 min.

Time: Placing Stay Post	Time: Shoveling Down	Time: Winding Up	Lost	Yards Per Car	Linear Ft. Track Per Yard	Yards Per Mile	Total Time Per Car	Total Hours Per Mile
8 min.	140 min.	8 min.	266 min.	30	3.3	2685	135 min.	645
2 min.	5 min.	5 min.	....	38	1.44	3152	20 min.	75
....	120 min.	20 min.	25 min.	25	2.7	1950	195.5 min.	254
....	27 min.	8 min.	93.5 min.	....	3.47	1520	135 min.	90

Table I-C—Time Required and Cost of Placing Ballast per Linear Foot of Track

Railway	Kind of Ballast	No. of Men: Foremen	No. of Men: Men	Average Height First Raise	Running Spot Board	Digging Jack Holes	Jacking Up Track
6 Cleaning Ballast..	Stone	1	14	3 in.	1.66 min.	2.1 min.	4.66 min.
7 Ballasting........	Stone	1	40	12 in.	0.5 min.	0.5 min.	2.0 min.
8 Ballasting........	Gravel	3	18	6 in.	0.21 min.	0.42 min.	1.0 min.
9 Ballasting........	Chats.	2	87	4 in.	0.024min.	0.24 min.	0.48 min.

Running Level Board	Forking and Tamping	Water Boy	Flag and Protection	Foremen	Total Time Per Linear Foot	Amount of Interference	Hours Per Mile
4.1 min.	9.3 min.	0.9 min.	5.91 min.	3.8 min.	28.96 min.	8.5%	2549
0.5 min.	14.5 min.	0.5 min.	1.0 min.	0.5 min.	20. min.	....	1760
0.21 min.	4.30 min.	....	....	....	6.14 min.	....	540
0.20 min.	9.136min.	0.36 min.	....	0.24 min.	10.68 min.	....	940

Table I-D—Time Required and Cost of Dressing Ballast per Linear Foot of Track

Railway	Single or Double Track	Kind of Material	No. of Men: Foremen	No. of Men: Laborers	Building Shoulder	Lining Edge of Ballast
6 Cleaning Ballast..	Double....	Stone......	1	9	6 min.	6 min.
7 Ballasting.........	Double....	Stone......	1	11	3.75 min.	2.5 min.
8 Ballasting........	Single.....	R. Gravel.	2	9	2.90 min.	1.18 min.
9 Ballasting.........	Single.....	Chats.....	1	56	2.40 min.	1.8 min.

Dressing Between Rails	Dressing Center Ditch	Moving Surplus Ballast	Foreman Time	Total Time Per Linear Foot	Delays	Total Man-Hours Per Mile
4.9 min.	4.9 min.	8.0 min.	3.21 min.	20.89 min.	11%	1842
1.375 min.	1.375 min.	5.0 min.	1.25 min.	14.5 min.	....	1276
1.10 min.	....	1.45 min.	1.72 min.	8.35 min.	....	735
3.0 min.	....	1.20 min.	0.15 min.	8.55 min.	....	752

TABLE I-E—RECAPITULATION—COST OF BALLASTING
COST PER MILE EXPRESSED IN PAY-ROLL HOURS

Railway	Kind of Ballast	Single or Double Track	Kind of Cars	Hours Skeletonizing Track	Unloading Ballast
6 Cleaning	Stone	Double	Hopper	9474	826 hr.
7 Ballasting	Stone	Double	Hopper	1529	75 hr.
8 Ballasting	R. Gravel	Single	Rog. Bal	634	254 hr.
9 Ballasting	Chats	Single	Rog. Bal	1204	90 hr.

First Raise	Unloading Ballast	Second Raise	Dressing Ballast	Lining Track	General Super-vision	Total Hours Labor	Work Eng. Hours	Train Car Hours
3003 hr.	890 hr.	830 hr.	1981 hr.	461 hr.	178 hr.	16972	73.1	91.6
1760 hr.	80 hr.	600 hr.	1276 hr.	80 hr.	150 hr.	5550	25.0	550.0
540 hr.	....	....	735 hr.	....	16 hr.	2170	21 0	462.0
940 hr.	....	440 hr.	753 hr.	80 hr.	10 hr.	2313	12 0	40.0

TABLE II—BALLASTING MAIN LINE

Railway	Year Work Was Done	Kind of Track	Kind of Ballast	Miles of Track	Cubic Yards of Ballast	Approximate Depth	Total
1	1913	Main	Stone	31.99	120,906	....	....
1	1910-11	Main	Stone	37.91	165,751	....	....
1	1914-15	Main	Stone	27.66	87,918	....	....
1	1910-12	Main	Stone	22 00	69,012	....	....
1	1914	Main	Stone	9 00	29,060	....	....
1	1913-14	Main	Stone	24.03	64,227	....	....
1	1911-12	Main	Stone	27.36	87,461	....	....
1	1912-13	Main	Stone	46.00	125,097	....	....
1	1911-13	Main	Stone	45.69	191,968	....	....
2	1917	Main	Stone	20.19	60,777	....	....
10	....	....	....	291.83	1,002,177	....	....
Averages	....	....	....	....	3,434	....	....
3	1917	Main	Gravel	0.55	3,700	24 in.	....
4	1913	Branch	Gravel	3.46	6,136	12 in.	....
4	1915	Branch	Gravel	3.78	6,697	12 in.	....
5	1909	Yard	Gravel	6.64	26,859	24 in.	....
5	1916	Yard	Gravel	1.90	5,916	18 in.	....
5	1917	Yard	Gravel	1.96	5,840	18 in.	....

Total Cost	Cost Man-Hours	Cost Per Cubic Yard	Cost Per Mile Track	Labor Rate	Hours at Rate	Cost Per Yard Man-Hours
$53,200	....	....	....	....	....	....
48,180	....	....	....	....	....	....
36,602	....	....	....	....	....	....
26,428	....	....	....	....	....	....
17,940	....	....	....	....	....	....
17,418	....	....	....	....	....	....
20,116	....	....	....	....	....	....
38,742	....	....	....	....	....	....
89,649	....	....	....	....	....	....
36,987	$138,603	$0.6857	$1,832	....	....	....
$385,262	....	....	$1,320	....	....	....
1,320	....	....	....	....	....	....
$ 1,060	....	$0.286	$1,927	$0.26	4,076	....
2,253	....	0.3672	651	.20	11,256	....
1,709	....	0.2552	452	.20	8,546	....
6,952	....	0.2588	1,047	.20	31,424	....
1,739	....	0.2940	915	.21½	8,089	....
2,036	....	0.3487	1,038	.26	7,832	....

Table No. III

Road No. 10

Amount $43,503.20.

Statement of cost of labor and material, ballasting 20 miles main line track between M. P. 229½ and 249½ with 8-inch slag placed under ties. Slag loaded by contract at 33 cents per cubic yard for first 20,000 yards and 23 cents per cubic yard for remainder, pit measurement. Contractor furnished all powder, labor and steam shovel for loading. Company furnished pit engine and crew. Work done August, 1912, to March, 1913, inclusive. Miscellaneous items, such as hand car turnouts, rail rests, etc., not included.

	Cost per cu. yd.
Loading—measurement on car	$ .19536
Pit engine and switching	.06788
Hauling	.10407
Unloading	.00783
Skeletonizing	.08287
Spacing, etc	.02423
Raising	.11977
Surfacing, lining and dressing	.14742
COST PER CU. YD. IN TRACK FINISHED	$ .74943

Number cu. yds. per mile	2600
Cost per mile ballast in place	$1948.52
No. ties inserted per mile	864
Average cost per tie	$ .75
Average cost per tie inserted	$ .076
Average train haul	22.5 miles

Road No. 10

Amount $53,150.00.

Statement of labor and material, ballasting 15 miles of track between M. P. 23.66 and 38.66 with 8 inches of slag placed under tie. Slag loaded by contract at 30 cents per cubic yard, contractor furnishing all powder, labor and steam shovel for loading; Company furnishing pit engine and crew; slag procured from dump of smelter at royalty of 10 cents per ton. Work done July, 1913, to January, 1914. Miscellaneous items, such as hand car turnouts, rail rests, etc., not included.

	Cost per cu. yd.
Royalty	$ .1587
Loading car measurement	.2323
Pit engine and switching	.0542
Hauling	.0803
Unloading	.0030
Skeletonizing	.0533
Spacing	.0121
Raising	.0730
Surfacing, lining and dressing	.1343
COST PER CU. YD. IN TRACK FINISHED	$ .8012

No. cu. yds. per mile	2684
Cost per mile ballast in place	$2150.42
No. ties inserted per mile	1221
Average cost per tie	$ .923
Average cost per tie inserted	$ .088
Average train haul	28.66 miles

Approximate swell of 22.5 per cent, not counting cost of engine and crew.

Road No. 10

AMOUNT $108,652.75.

Statement of labor and material, ballasting 29.34 miles of track between M. P. 38.66 and M. P. 68.0 with 8 inches of slag placed under tie. Slag loaded by contract at 30 cents per cubic yard. Contractor furnishing all powder, labor and steam shovel for loading, company furnishing pit engine and crew. Slag procured from dump of smelter at a royalty of 10 cents per ton. Work done August, 1913, to January, 1914. Miscellaneous items, such as hand car turnouts, rail rests, etc., not included.

	Cost per cu. yd.
Royalty	$ .1587
Loading car measurement	.2285
Pit engine and switching	.0697
Hauling	.1297
Unloading	.0026
Skeletonizing	.0528
Spacing	.0124
Raising	.0904
Surfacing, Lining and dressing	.0973
COST PER CU. YD. IN TRACK FINISHED	$ .8421

No. cu. yds. per mile	2684
Cost per mile ballast in place	$2218.09
No. of ties inserted per mile	980
Average cost per tie	$ 1.006
Average cost per tie inserted	$ .099
Average train haul	50.83 miles

Approximately 23.8 per cent swell.

Road No. 10

AMOUNT $71,435.00.

Statement of labor and material, ballasting 20½ miles of track between M. P. 118 and M. P. 132½, with 8 inches of slag placed under ties. Slag loaded on cars by contract for 23 cents per cubic yard, pit measurement. Work done February to June, 1914. Miscellaneous items, such as hand car turnouts, rail rests, etc., not included.

		Cost per yard
Loading measurement on car	10171.45	$ .1908
Pit engine and switching	3478.55	.0653
Hauling	12704.74	.2384
Unloading	209.36	.0039
Skeletonizing	2235.45	.0419
Spacing	280.14	.0053
Raising	5020.15	.0942
Surfacing, lining and dressing	6087.12	.1142
	40186.96	$ .7540

Number cubic yards per mile	2600
Cost per mile ballast in place	$1960.4
No. ties inserted per mile	916
Average cost per tie	$ 0.973
Average cost per tie for inserting	$ 0.079
Average train haul	89 miles

Road No. 10

AMOUNT $56,569.30.

Statement of labor and material, ballasting 17.67 miles of track between M. P. 99 and 116.67 with 8 inches of slag placed under ties. Slag loaded on cars by contract for 23 cents per cubic yard, pit measurement; work done April to July, 1914. Miscellaneous items, such as rail rests, hand car turnouts, etc., not included.

		Cost per yard
Loading measurement on car	7624.64	$ .1726
Pit engine and switching	2414 07	.0546
Hauling	11787.56	2671
Unloading	196.54	.0044
Skeletonizing	2552.39	.0578
Spacing	154 24	.0033
Raising	4171.87	.0944
Surfacing, lining and dressing	4492.29	.1017
	33393.60	$ .7559
Number cubic yards per mile		2500
Cost per mile ballast in place		$ 1889.75
No. ties inserted per mile		1001.
Average cost per tie		$ 0.94
Average cost per tie for inserting		$ 0.098
Average train haul		109 miles

Road No. 10

AMOUNT $85,915.00.

Work performed May to August, 1914. Statement of labor and material, ballasting 25 miles of track, between M. P. 74 and M. P. 99, with 8-inch slag placed under ties. Slag loaded on cars by contract for 23 cents per cubic yard, pit measurement. Miscellaneous items, such as rail rests, hand car turnouts, etc., not included.

		Cost per yard
Loading measurement on car	12707.37	$ .1955
Pit engine and switching	3495.69	.0538
Hauling	19858.02	.3055
Unloading	271.50	.0042
Skeletonizing	3082.71	.0474
Spacing	226.50	.0035
Raising	5842.25	.0899
Surfacing, lining and dressing	6600.86	.1016
	52084.90	$ .8014

Number of cubic yards per mile	2600
Cost per mile ballast in place	$2083.64
No. of ties inserted per mile	1261
Average cost per tie	$ 1.07
Average cost per tie for inserting	$ .086
Average train haul	130½ miles

Table No. IV

Road No. 11

Summarized Statement of Ballast Operations During the Year 1918

167.5 miles of track ballasting during the year 1918. Gravel ballasting, average lift 4 to 6 inches. Cost of train haul, $87,630.32. Total cost, $375,229.31.

Rate of Wages Paid Extra Gang Men and Men Employed in Train Service

Extra Gang Foreman	$7.15 per day
Extra Gang Laborers	3.00 per day
Steam shovel engineer	6.32½ per day
Steam shovel crane man	4.95 per day
Steam shovel fireman	3.50 per day
Watchman	3.40 per day
Cook	3.00 per day
Rapid unloaderman	4.70 per day
Pit man	3.50 per day

Cost of Ballasting—Season 1918

Items as shown on Form furnished by the Chairman of Valuation Committee	District B	
1 Year purchased	....	
2 Source of supply	Ballast Pit C	
3 No. of cu. yds. supplied during year	72,082	
4 Miles ballasted during year	18 miles	
5 Location ballasted	Portions of line on 5th District between following points: West end of Bridge to east end C Junction Yard. S Station to MP 64.	
6 From whom purchased	Ballast taken from Company's own ballast lands.	
7 Point of delivery from Carrier's line	Taken from C Ballast Pit MP 122.55. Average distance ballast hauled, 157 miles.	
8 F. O. B. point	....	
9 Items of Cost		
10 Cost at source of supply:		
(a) Fixed charges for pit	72.08	0.1c
(b) Operation of pit	12,671.38	17½c
11 Freight charges, i. e.: Cost of hauling ballast	26,627.69	37c
12 Switching charges	This charge is included in above charges.	
13 Cost of unloading and spreading ballast	7,329.35	10c
14 Other expenses, i. e.: Applying ballast	37,148.96	51½c
15 Grand Total	83,993.63	116.1c

Cost of Ballasting—Season 1919

Items as shown on Form furnished by the Chairman of Valuation Committee	District A	District B
1 Year purchased............		
2 Source of supply...........	Ballast Pit C	Pits C and N
3 No. of cu. yds. supplied during year...............	114,548	135,433
4 Miles ballasted during year..	48 miles	83 miles
5 Location ballasted..........	Portions of line between following Mile Posts: MP 10–18, 28– 35, 60– 72, 107–117	Portions of line between following Mile Posts: MP 4– 11, 13– 19, 21– 44, 54– 58, 65– 92, 96– 97, 101–110, 116–118, 119–125
6 From whom purchased......	Ballast taken from Company's own ballast lands.	Ballast taken from Company's own ballast lands.
7 Point of delivery from Carrier's line................	Average distance over which ballast was hauled, 60 miles.	34,000 cu. yds. hauled average distance of 190 miles. Remainder hauled average distance of 160 miles.
8 F.O.B. point...............		

9 Items of Cost	Amount, $	Per Cu.Yd. Cents	Amount, $	Per Cu.Yd. Cents
10 Cost at source of supply:				
(a) Fixed charges for pit...........	801.84	0.7	2,256.29	2
(b) Operation of pit.	25,381.91	22.16	24,379.40	18
11 Freight charges, i.e.: Cost of hauling ballast.........	22,842.08	19.94	42,416.15	31.32
12 Switching charges. .	This charge is included in above charges.			
13 Cost of unloading and spreading ballast.	19,731.33	17.22	23,578.72	17.41
14 Other expenses: Applying ballast..	60,265.92	52.61	79,990.65	59.06
15 Grand Total........	$129,023.08	$1.125	$172,621.21	$1.275

COST OF BALLASTING—SEASON 1919

Items as shown on Form furnished by the Chairman of Valuation Committee.	District C	District D
1 Year purchased.......	Not known...........	Not known.
2 Source of supply......	H Ballast Pit.........	H Pit.
3 No. cu. yds. supplied during year.........	33,976................	14,908
4 Miles ballasted.......	11 miles..............	5½ miles.
5 Location ballasted....	At various points between MP 4 and MP 133.................	At various points between 181 and 204
6 From whom purchased	Ballast taken from Co.'s own ballast lands...............	Ballast taken from Co.'s own ballast lands.
7 Point of delivery from Carrier's line........	Average distance over which ballast was hauled, 120 miles....	Average distance over which ballast was hauled, 6 miles.
8 F. O. B. point.........	....	....

9 Items of Cost	Amount $	Per cu. yd. c.	Amount $	Per cu. yd. c.
10 Cost at source of supply:				
(a) Fixed charges for pit.................	713.50	2.1	313.07	2.1
(b) Operation of pit...	5,072.18	14.9	3,558.21	23.9
11 Freight charges, i. e.: Cost of handling ballast................	11,428.94	33.6	1,323.00	8.9
12 Switching charges.....	This char	ge is included	in above c	harges.
13 Cost of unloading and spreading ballast....	5,204.21	15.3	968.40	6.5
14 Other expenses: Applying ballast....	9,522.94	28.0	4,640.38	31.1
15 Grand Total..........	$31,941.77	93.9c	10,803.06	72½c

COST OF BALLASTING—SEASON 1919

Items as shown on Form furnished by the Valuation Committee	District E	District F	District G
1 Year purchased.....	Not known	Not known	Not known
2 Source of supply....	Q Ballast Pit	Q Pit	G Bal. Pit
3 No. of cu. yds.......	7988	5411	14,274
4 Miles ballasted.....	5 miles	6 Mi. of Tr. (Surfaced and shouldered)	9¼ miles
5 Location ballasted..	Portions of line between following points: MP 222–229 MP 232–234	MP 14–28 Main Line: MP 62–½–70 70–½–75 76–78 82–82–½	At various points between: MP 52–53 89–90 93–105 116–119 122–127 140–146
6 From whom purchased...........	Ballast taken from Co.'s own pits.	Ballast taken from Co.'s own pits.	Ballast taken from Co.'s own pits.
7 Point of delivery from Carrier's line.	Av. dist. over which ballast was hauled, 50 miles	Av. dist. over which ballast was hauled, 35 miles	Av. dist. over which ballast was hauled, 32 miles
8 F.O.B. point........	Not known	Not known	Not known

9 Items of Cost	Amount $	Per Cu.Yd. Cents	Amount $	Per Cu.Yd. Cents	Amount $	Per Cu.Yd. Cents
10 Cost at source of supply.						
(a) Fixed charges...	518.70	6.5	351.72	6.5	863.07	6.0
(b) Operation of pit.	3,681.46	45.8	2,440.40	45.1	5,418.06	37.9
11 Freight charges, i.e.: Cost of hauling ballast............	1,571.46	19.7	1,125.93	20.8	3,925.17	27.5
12 Switching charges...	This c	harge is	included	in abo	ve charg	es.
13 Cost of unloading and spreading ballast..	1,695.26	21.3	1,637.61	30.2	2,440.56	17.1
14 Other expenses: Applying ballast..	2,761.31	34.6	629.08	11.6	5,602.40	39.3
15 Grand Total........	$9,408.19	127.9c	$6,184.74	114.2c	$15,247.26	127.8c

TABLE V

Road No. 12

TIME AND COST STUDY OF BALLASTING PREPARED IN ANSWER TO QUESTIONNAIRE OF THE AMERICAN RAILWAY ENGINEERING ASSOCIATION

Job 1.—Rock Ballast—4-In. Raise

	Cost per Mile
Work Train	$ 713
Track Dug	904
Ballast Distributed	143
Final Raise	1020
Line and Finish	1102
Spacing Ties	200

Job 2.—Gravel Ballast—6-In. Raise

Work Train	$ 497
Track Dug	290
Ballast Distributed	52
Final Raise	479
Line and Finish	895
Spacing Ties	588

Job 3.—Rock Ballast—8-In. Raise

Work Train	$ 502
Track Dug	552
Ballast Distributed	137
First Raise	628
Final Raise	433
Line and Finish	516
Spacing Ties	470

Jobs Nos. 1 and 2

Work done July-September, 1920

Wage rates—Laborers ....48½c per hour
Foremen ....74c per hour

Jobs Nos. 3, 4, 5 and 6

Work done July-September, 1920

Wage rates—Laborers ....42½c per hour
Foremen ....74c per hour

Job 4.—Slag Ballast—8-In. Raise

	Cost per Mile
Work Train	$ 426
Track Dug	489
Ballast Distributed	98
First Raise	525
Final Raise	519
Line and Finish	528
Spacing Ties	263

Job 5.—Slag—8-In. Raise

Work Train	$ 791
Track Dug	690
Ballast Distributed	132
First Raise	616
Final Raise	594
Line and Finish	834
Spacing Ties	533

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Job 6.—Rock—8-In. Raise

Work Train	$ 368
Track Dug	392
Ballast Distributed	137
First Raise	515
Final Raise	478
Line and Finish	506
Spacing Ties	371

TABLE NO. VI

Road No. 13

ORGANIZATION, METHODS, AND COSTS OF CONVERTING ONE MILE OF TRACK (SINGLE AND DOUBLE) FROM CINDER OR GRAVEL BALLASTED TRACK TO STANDARD SECTION STONE BALLASTED TRACK

1. **Stripping Track.**
2. **Unloading Ballast (Various Types of Cars).**
3. **Raising Track on New Ballast (1 or 2 Lifts).**
4. **Dressing Ballast.**

(1) **Stripping Track.**

(a) **Object**—To remove existing gravel or cinder ballast to the bottom of the ties in cribs, center-ditch and shoulder. Old material to be cast over the bank on fill and removed by work train from cuts.

(b) **Organization**—16 men, 1 foreman. Gang should be kept one or two days' work ahead of ballasting gang to allow room for unloading ballast cars. Each man carries a pick, No. 2 shovel and scoop shovel.

Each man in gang is assigned one-half rail length of track to strip. Upon completion he moves to the first one-half rail length ahead of the leading man. Thus the men are all one-half rail length apart. The gang of 16 men being spread out over 8 rail lengths.

(c) **Method**—Shoveling should start at the shoulder and work toward the center-ditch, first loosening the crib with pick if necessary. When working the cribs each man uses his No. 2 shovel on account of the narrow space, but the material in shoulder and center ditch should be handled with scoop shovel.

(d) **Cost**—The cost of this work, expressed in payroll hours, has been determined very closely by time-studies of actual performance. Several studies were made on different gangs engaged in this work, and the results consolidated into a schedule of performance which has been called a standard of 100 per cent efficiency, as shown below.

Time required to remove one cubic yard of material (including foreman's time):

Material removed—	*Time Required*
Cribs	45 minutes = .75 hours
Centerditch	26 minutes = .433 hours
Shoulders	26 minutes = .433 hours

Hours required per linear foot of double track (13 ft. centers)..0.230
Hour required per linear foot of single track..................0.101

In arriving at these figures the following cubical contents were used:

1 linear ft. of double track (13 ft. centers)....9.77 c. f. = .36 cub. yds.
1 linear ft. of single track....................3.99 c. f. = .15 cub. yds.

From this schedule the cost of stripping one mile of track with a gang working at 100 per cent efficient would be as follows:

Double Track (13 ft. centers)...5280 × 0.230 = 1214.40 payroll hours
Single Track ....5280 × 0.101 = 533.28 payroll hours

Since, however, experience shows that track gangs do not often work at 100 per cent efficiency, but as a general rule have averaged nearer 80 per cent and are detained by passing trains and other causes to the amount of 10 per cent, the foregoing cost hours are increased to the following:

Double Track (13 ft. centers)......5280 × 0.316 = 1667 payroll hours
Single Track ....5280 × 0.139 = 732 payroll hours

(2) Unloading Ballast.

(A) Object—To drop sufficient ballast along the stripped track to replace all old ballast removed and give standard ballast sections when dressed.

(B) Organization—The ballast unloading gang will, of course, vary with the different kinds of cars in which the ballast is delivered. In this connection, it is, of course, most economical to use an approved type of specially constructed ballast car, such, for instance, as the Roger Ballast Car, which will drop the stone either between or outside the rails. The gang required when special ballast car is used is 2 men and 1 foreman. The foreman releases pockets and the two men handle tie and shoes and jar ballast down. When using 100,000-lb. hopper cars, 8 men and 1 foreman are required. Foreman and 4 men stay on ground to place shoes and ties, open the pockets and jar ballast down. The other four men stay on the car and shovel the ballast down. The same size gang is also required to unload 100,000-lb. drop-bottom gondolas. In this case the foreman and four men remain on the ground to place shoes and tie, and open pockets. When all is ready for plowing the four men on ground get into the car and assist the other four men in shoveling the ballast down through the pockets.

(C) Method—Special ballast cars can be unloaded in strings of as high as 10 at one time and the flow of the ballast through pockets can easily be regulated. A cross-tie is placed in front of rear truck and shoes placed behind it, on which the wheels mount and slide shoe and tie along rail, plowing the ballast off to level of top of rail. Foreman personally attends to lowering of the pockets and has sufficient men on the ground to handle tie and shoes and jar ballast down, and sufficient men in the car to keep ballast moving to the pockets. Each gang has two wrenches and two wooden mauls to hammer the sides of hoppers and gondolas to jar down the ballast. Car pockets must always be closed before foreman releases train.

(D) Cost—From a large number of time studies on different gangs the following schedule was arrived at and called a 100 per cent performance:

			(Time required)
Operation	*100,000-lb. Gondolas*	*100,000-lb. Hopper*	*Roger Ballast Cars*
Placing shoes	4	4	4 minutes
Removing shoes from empty	4	4	4
Waiting to release bottoms	16	16	6
Placing ties	4	3	3
Removing tie from empty	4	3	3
Placing stay-post	..	4	..
Releasing drop bottoms	12	4	3
Winding up drop bottoms	12	8	3
Jarring and shoveling down	264	16	6
Foreman's time	32	6	..
Total minutes for one car	352	66	33
Hours per car	.87	1.1	0.55
Load of each car in cubic yards	35	35	28

Cubic yards to the mile required:

Double Track (13-ft. centers)........... .36 × 5280 = 1900.8 cu. yds.
Single Track .... .15 × 5280 = 792.0 cu. yds.

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Thus the cost in payroll hours of unloading ballast for 1 mile of track based on 100 per cent efficiency would be:

Type of Car	*Double* *Cars per Mile*	*Single*	*Cost per Car*	*Double* *Cost per Mile*	*Single*
100,000-lb. Gondolas.....	57	23	5.87	335	135
100,000-lb. Hoppers......	57	23	1.1	63	25
Roger Ballast	68	28	0.55	37	16

Assuming an average performance of 80 per cent and adding 10 per cent for lost time or detention: The foregoing costs become

Cost per Mile	*Double*	*Single*
100,000-lb. Gondola..	460 + 6.4 days W. T. serv. =	186 + 2.6 W. T. serv.
100,000-lb. Hopper...	87 + 1.2 days W. T. serv. =	34 + 0.5 W. T. serv.
Roger Ballast	51 + 1.9 days W. T. serv. =	22 + 0.8 W. T. serv.

This operation to be followed by raising the track on the new ballast in either one or two lifts, according to the depth of ballast desired under the ties. If one lift only is made, the unloading cost must be doubled. If two lifts are made, ballast will have to be dragged three times, and since the amount dropped in such dragging is very nearly the same, the cost will be three times the figures shown above.

(3) Raising Track (One or Two Lifts).

(A) Object—To lift the track (4″ to 6″ per lift) and fork the ballast in cribs, shoulder and center-ditch under the ties, using all new ballast available to get as good a raise as possible. Height of raise and number of lifts depend, of course, on depth of ballast desired under ties.

(B) Organization—A good and well balanced gang for this work includes 1 foreman and 20 men. One man flags in each direction, 6 men handle jacks (three men per jack) and tamp joint and center ties. One jack man runs level board, and one forks ballast under ties for tamping. Ten men follow the jack men, completing tamping. On double track two such units may be worked side by side.

(C) Method—When work is started a flagman is sent out in either direction. Two men work ahead of gang and dig jack holes at joints and centers and run spot-board. Two men with each jack assisted by one man forking ballast under ties for tamping. One of the jack men also runs the level-board to assure correct cross level. The other ten men follow, tamping with forks inside and outside of rail (tamp 18 in. from gauge line inside).

(D) Cost—The cost, in payroll hours, of one raise of four to six inches, tamping with forks only, to be followed immediately by another raise and retamping, is expressed in the following schedule, based on a 20-man gang performing at 100 per cent efficiency.

First Raise

Operation	*Minutes per Foot of One Track*
Running spot-board	0.07
Digging jack holes	0.71
Jacking up track	0.68
Running level board	0.09
Tamping, outside of rail only	2.10
Waterboy	0.18
Two flagmen	0.36
Foreman's time	0.18
Minutes per ft. of 1 track	4.37
Hours per ft. of 1 track	0.072

Assuming an 80 per cent performance for this gang and allowing 10 per cent for detention and lost time, the cost per ft. of one track becomes:

Hours per ft. of one track....................0.090 plus 10% = 0.099

Second Raise

Operation	*Minutes per Foot of One Track*
Running spot-board	0.07
Digging jack holes	0.71
Jacking up track	0.85
Running level-board	0.20
Tamping inside and outside of rail	4.10
Water boy	0.30
Two flagmen	0.60
Foreman	0.30
Minutes per foot of one track	7.13
Hours per foot of one track	0.119

At 80 per cent efficient performance and 10 per cent detention, the cost per foot of one track becomes:

Hours per foot of one track..................0.149 plus 10% = 0.164

Where only one raise is made the cost shown under "second raise" should be used, as more careful and complete tamping is done.

Cost per mile of one track:

1 Raise ....0.164 × 5280 = 866 Payroll Hours
2 Raise ....0.263 × 5280 = 1389 Payroll Hours

(4) Dressing Ballast.

(A) Object—To fork excess stone from between the rails, build standard shoulder and level the stone in center-ditch, to give the standard ballast section.

(B) Organization—1 foreman and 9 men make a well-balanced gang for this work. Two men leveling berme, two men building stone line, two men forking stone from between rails, two men dressing shoulder and one man leveling center-ditch.

(C) Method—Two men keep ahead straightening and leveling up the berme. Immediately behind the berme-builders one man forks stone from between rails while another uses template and ballast-board on shoulder, drawing stone down to board-line with fork in sufficient quantity to properly define the stone-line. These men are followed by others, working in pairs, one forking from between rails and the other dressing up shoulder or center-ditch. Proper distribution of ballast by work train is essential to economical results.

(D) Cost—The following schedule, based on many time studies, represents a 100 per cent performance for a gang of 9 men and foremen:

Operation	*Total Time Required per Ft. Double Track*
Building berme	1.4 minutes
Building stone lines	0.6 "
Forking ballast from between rails	6.6 "
Dressing shoulders	1.6 "
Dressing center-ditch	0.9 "
Foreman's time	1.1 "
Minutes per ft. of double track	12.2
Hours per ft. of double track	.203
Hours per ft. of single track	.186

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Assuming a performance of 80 per cent and adding 10 per cent for lost time or detention, these figures become:

Hours per ft. of double track.......................... .278
Hours per ft. of single track.......................... .232

Cost per mile then would be:

Double track ....5280 × .278 = 1468 payroll hours
Single track ....5280 × .232 = 1225 payroll hours

Recapitulation

Cost per mile of single and double track.

(1) One raise, giving from four to six inches of ballast under ties.

Ballast Deivered in	*100,000-lb. Gondolas*		*100,000-lb. Hoppers*		*Roger Ballast Car*	
Item	*Single*	*Double*	*Single*	*Double*	*Single*	*Double*
Stripping track......	732	1667	732	1667	732	1667
1—Unloading ballast....	186	460	34	87	22	51
Raising track	866	1732	866	1732	866	1732
2—Unloading ballast....	186	460	34	87	22	51
Dressing ballast.....	1225	1468	1225	1468	1225	1468
Total	3195	5787	2891	5041	2867	4969
			Payroll Hours			
Plus W. T. Service in 8-hr. days......	5.2	12.8	1.0	2.4	1.6	3.8

Cost per mile of single track and double track.

(One) Two raises, giving from 10 to 12 inches of ballast under ties.

Ballast Delivered in	*100,000-lb. Gondolas*		*100,000-lb. Hoppers*		*Roger Ballast Cars*	
	Single	*Double*	*Single*	*Double*	*Single*	*Double*
Stripping track	732	1667	732	1667	732	1667
1—Unloading ballast....	186	460	34	87	22	51
1—Raising track	523	1045	523	1045	523	1045
2—Unloading ballast....	186	460	34	87	22	51
2—Raising track	866	1732	866	1732	866	1732
3—Unloading ballast....	186	460	34	87	22	51
Dressing ballast	1225	1468	1225	1468	1225	1468
Total	3904	7292	3448	6173	3412	6065
			Payroll Hours			
Plus W. T. Service in 8-hr. days......	7.8	19.2	1.5	3.6	2.4	5.7

The Costs of Ballasting, as given above, are the bona fide figures presented by representative railways of the United States of America and of Canada, and are offered to the Association as information.

Appendix C

ITEM 3—BALLAST TOOLS

A. G. Holt, *Chairman;*
C. E. Dare,
Hans Schantl,
Paul Sterling,
Sub-Committee.

The Committee was instructed to make final report if practicable on the subject of Ballast Tools.

Ballast Shovel

The report of the Committee presented to the 1921 Convention included a suggested design for a track shovel. The sub-committee has during the past year investigated the matter of handle design with special reference to the "D." It is found that the old style wooden "D" handle requires in its manufacture a large waste of material and also is very apt to be broken in use, thereby resulting in the loss of the entire shovel unless some other form of "D," which can be applied to a handle with a broken "D," is available. The malleable iron "D" as furnished in the past has not been altogether satisfactory, largely, it is felt, because of the metal spool or hand hold.

With a view to developing the utility and practicability of "D's" which can be applied to handles without "D's" the Committee has prepared the designs which are shown herewith. It is hoped that the types of handles shown will be tried out and the Committee will be able to secure information which will enable it to recommend a definite design.

Specifications for ballast shovels have been prepared and are presented herewith. The Committee recommends the adoption of these specifications as recommended practice.

Spot Board

The sub-committee has also prepared a design for a spot board with the necessary holders and raising blocks. This follows the design which is quite generally used on various railroads and is recommended for adoption as recommended practice and inclusion in the Manual.

SPECIFICATIONS FOR BALLAST SHOVELS

Scope.

1. These specifications cover ballast shovels.

Material.

2. Blades shall be open hearth, crucible or alloy steel.
3. Straps shall be of softer steel than blades.
4. Handles shall be smooth and properly seasoned of the best grade straight, grained, commercial XX second growth, northern ash.

Design.

5. The dimensions of shovels shall conform to plans which are made a part of these specifications.

6. Carbon steel blades shall be not less than No. 13 gauge and alloy blades shall be not less than 14 gauge U. S. standard.

7. The straps shall be one gauge heavier than the blade and rolled down to one gauge lighter at the extreme and farthest end and shall be welded or riveted to the blade.

8. The straps shall be pressed flush with the handle. All the rough edges pressed down to uniform surface with the other parts of the handle and fastened to the handle by three rivets, the edges of which shall be pressed down flush with the surface of the straps.

Physical Properties.

9. Shovels shall be made in a workmanlike manner and free from all defects. The handles shall be bent to shape and free from knots, shake, wane or worm holes.

10. The blades shall be of natural color and coated with a high proof rust preventative and the entire strap shall be polished.

11. Blades shall show a Brinell hardness of not less than 300, readings to be taken anywhere on the blade and the Brinell readings shall not show greater than 400 in a carbon blade or 470 in an alloy blade.

12. The shovel as a whole shall not be deformed permanently more than ½ inch of its lift after six 2-minute applications made at 2-minute intervals of the following test:

The point of the blade shall rest on a support; at a point 10½ inches from the edge of the blade, a chain shall be passed over the heel of the blade and drawn up and blocked with no slack and to be fastened to an I-bolt in the floor; a ratchet jack standing on a platform scale shall be placed under the "D" of the handle and the jack pumped until 175 lb. (plus the weight of the jack and the paraphernalia used in making the test) is registered on the beam of the scale.

13. The manufacturer's name, quality of the steel and the date of manufacture shall be stamped plainly on the back strap and the name of the railroad shall be stamped on the front strap of each shovel.

Inspection.

14. For the Brinell test and the test of strength, the inspector shall select at random one shovel from every ten dozen of each type purchased and should this shovel fail to meet the requirements in paragraphs 11 and 12, two more shovels shall be selected from the ten dozen and both must meet the specification requirements.

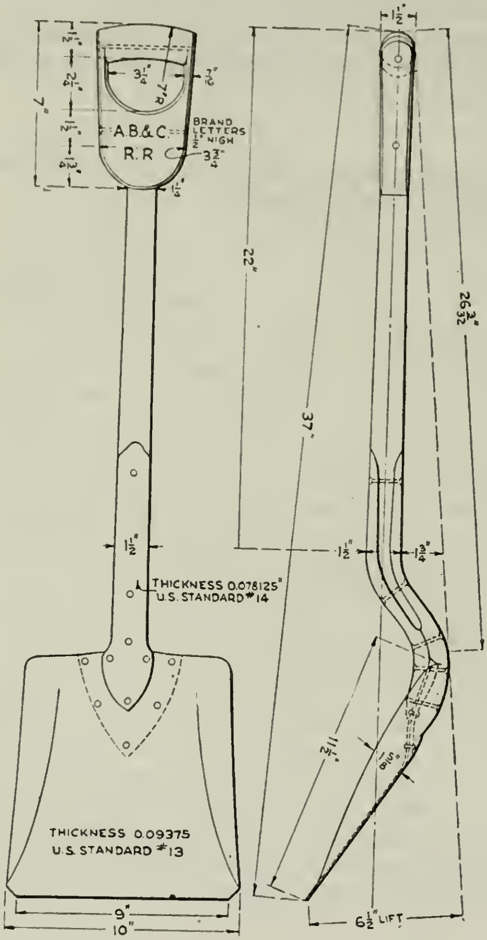
15. Inspection of tools shall ordinarily be made at the place of manufacture. The manufacturer shall notify.................................. of the railroad company at least..........days in advance when shovels will be ready for shipment.

16. The manufacturer shall allow the railroad company's inspectors such access to the work as may be necessary to satisfy them that the provisions of these specifications are carried out.

17. The manufacturer shall furnish, without charge, all necessary facilities, and assistants, for making thorough inspection and tests at the works.

Rejection.

18. Individual tools, defective in any respect, and lots of tools not meeting the above requirements, shall be rejected.



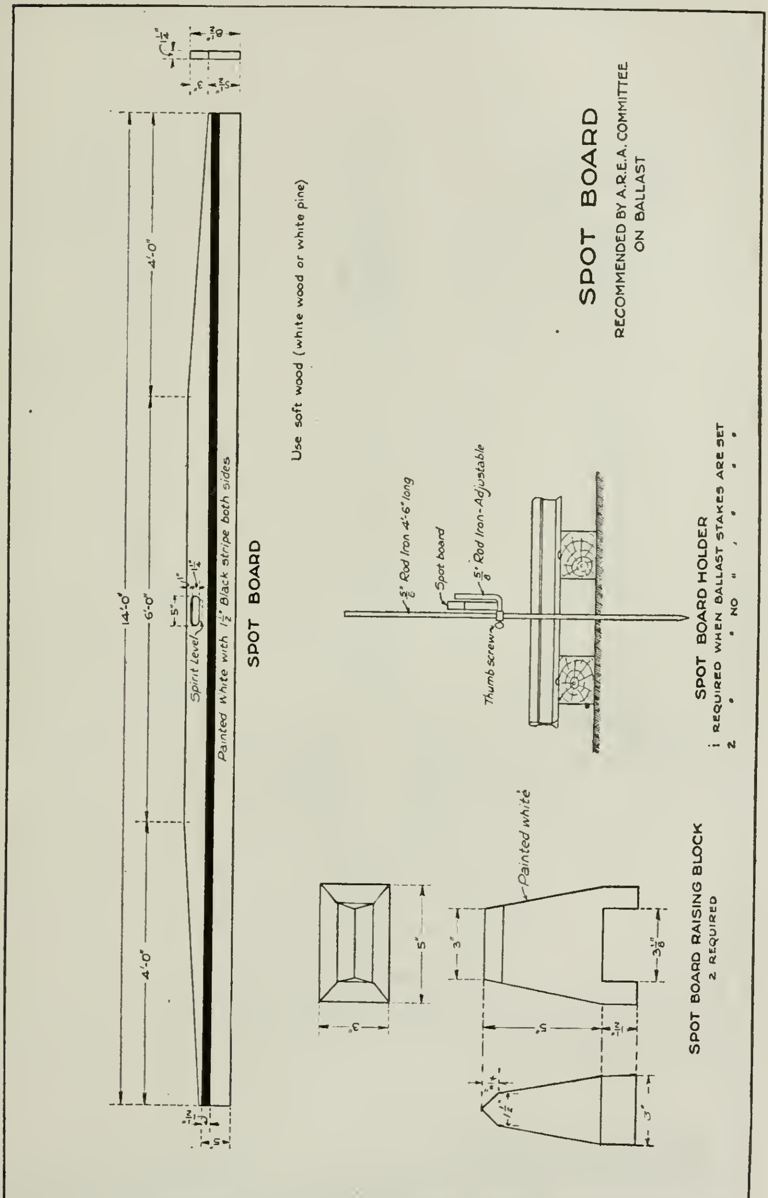
Weight approx. 5 3/4 lbs.

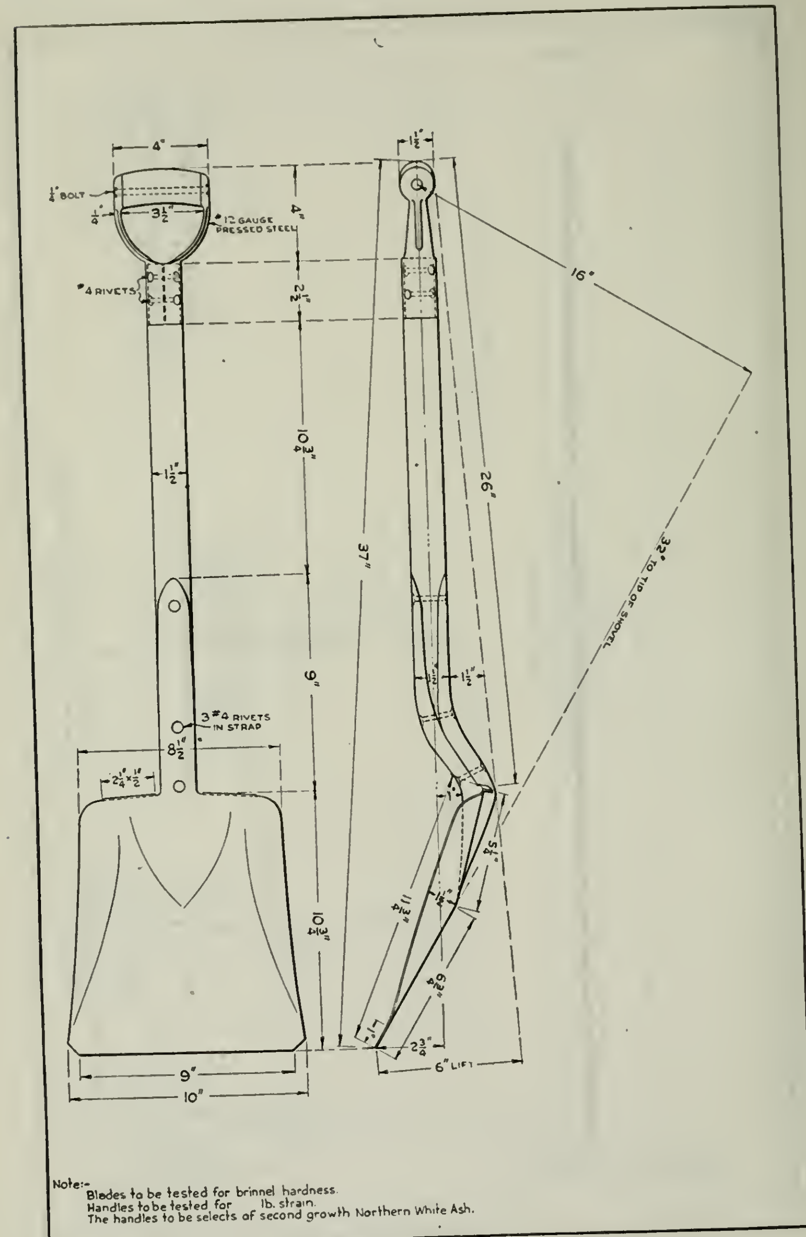
Name of manufacturer with month and year made to be stamped on strap.

The following variations in dimensions shown on plan will be permitted:–

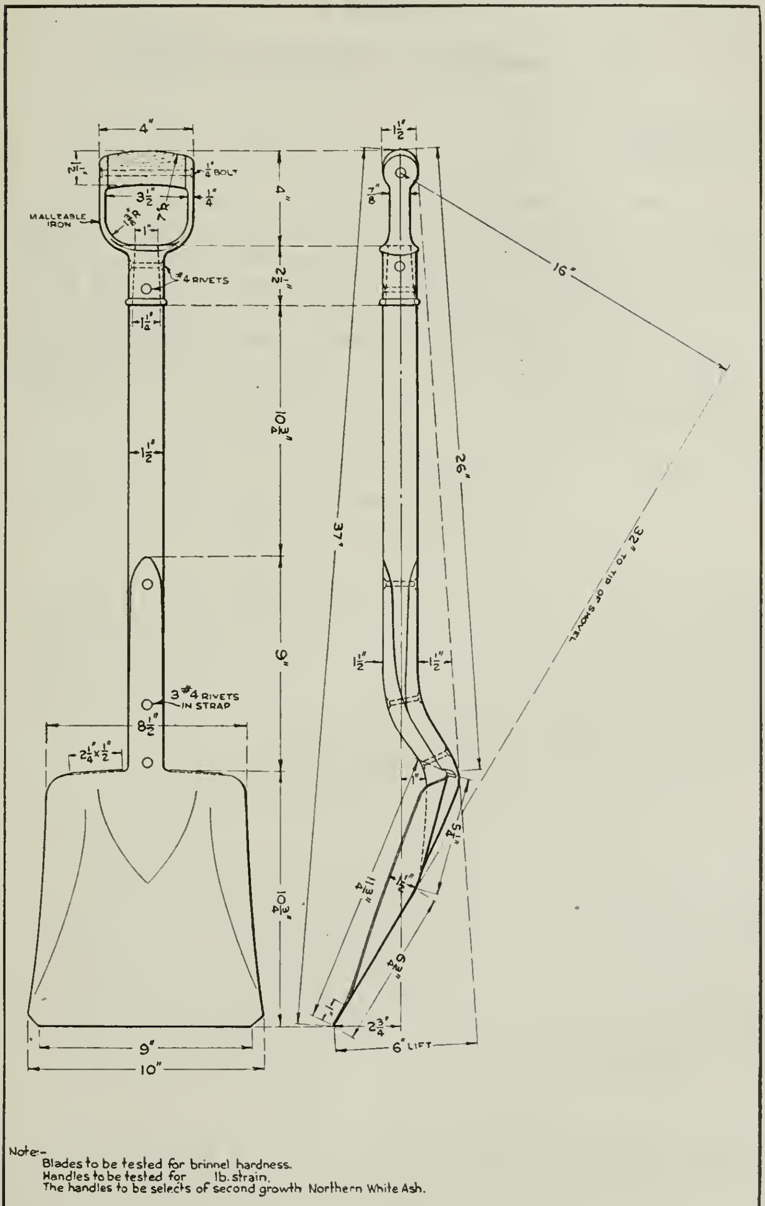
Length of handle 1".
" " blade 3/8".
Width of blade 1/4" less.
Lift " " 1/2".

BALLAST SHOVEL


SPOT BOARD
RECOMMENDED BY A.R.E.A. COMMITTEE ON BALLAST
14'-0"
4'-0"
6'-0"
4'-0"
Spirit Level
Painted White with 1½" Black stripe both sides
SPOT BOARD
Use soft wood (white wood or white pine)
5/8" Rod Iron 4'-6" long
Spot board
5/8" Rod Iron-Adjustable
Thumb screw
SPOT BOARD HOLDER
1 REQUIRED WHEN BALLAST STAKES ARE SET
2 " " NO " " "
Painted white
SPOT BOARD RAISING BLOCK
2 REQUIRED



Pressed Steel "D" With Wooden Spool



Malleable Iron "D" With Wooden Spool

Appendix D

ITEM 4—REVIEW OF PREVIOUS REPORTS

G. H. Harris, *Chairman;*
Paul Hamilton,
F. A. Jones,
H. L. Ripley,
M. A. Stainer,
Sub-Committee.

The Sub-Committee after reviewing much of the previous work of the Committee and attempting to reduce it to a form for presentation, discovered that the result would be nothing more than an index. In view of the fact that there is now an index in book form for all matter prior to 1915; that each year's proceedings contains a complete index and that if an index were now prepared and published as part of the 1922 report it would be no more available after the lapse of a year or so than the indices in the individual volumes, the recommendation is made that the subject be dropped.

REPORT OF COMMITTEE XV—IRON AND STEEL STRUCTURES

O. E. Selby, *Chairman;*
F. Auryansen,
J. A. Bohland,
W. S. Bouton,
A. W. Carpenter,
M. F. Clements,
J. E. Crawford,
O. F. Dalstrom,
F. O. Dufour,
Thos. Earle,
W. R. Edwards,
C. R. Fickes,
G. A. Haggander,
R. L. Huntley,
B. R. Leffler,
P. G. Lang, Jr.,

P. B. Motley, *Vice-Chairman;*
Albert Reichmann,
O. B. Robbins,
A. F. Robinson,
H. N. Rodenbaugh,
W. R. Roof,
J. M. Salmon,
I. L. Simmons,
I. F. Stern,
H. B. Stuart,
G. E. Tebbetts,
F. E. Turneaure,
Dr. J. A. L. Waddell,
S. T. Wagner,
H. T. Welty,
Committee.

To the American Railway Engineering Association:

The Committee on Iron and Steel Structures respectfully presents herewith its annual report to the Association.

Subject No. 1. Revision of Manual

In the General Specifications for Steel Railway Bridges, 1920, three changes are recommended. The Committee is reluctant to make changes in these specifications which have been adopted so recently and received so favorably, but these few changes will correct inconsistencies and supply an obvious omission. They should be adopted now and promulgated pending a more extended revision of the Specifications which may be needed after the lapse of five or ten years. The changes are of such a nature that the Specifications still may bear the date of 1920 and existing copies may be corrected by the use of pasters or otherwise.

Following are the changes recommended for adoption and printing in the Manual:

Article 47—Change the last sentence to read: "The unit stresses specified in Article 38 may be increased one-third for a combination of the secondary stresses with the other stresses, but the section shall not be less than that required when secondary stresses are not considered."

Article 48—Change to read: "The gross area of the compression flanges of plate girders and rolled beams shall not be less than the gross area of the tension flanges, but the stress per square inch shall not exceed

$$\underline{16000} - \underline{150}\,\frac{l}{b}, \text{ in which}$$

l = the length of the unsupported flange between lateral connections or knee braces.

b = the flange width."

A

Article 243—Omit all of the fourth sentence after the word "Engineer," making the Article read:

Eye-Bars.

243. Eye-bars shall be straight, true to size, and free from twists, folds in the neck or head, and other defects. The heads shall be made by upsetting, rolling or forging. Welding will not be allowed. The form of the heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the Engineer. The thickness of the head and neck shall not overrun more than $\frac{1}{16}$-inch for bars 8 inches or less in width, $\frac{1}{8}$-inch for bars more than 8 inches and not more than 12 inches in width, and $\frac{3}{16}$-inch for bars more than 12 inches wide.

Subject No. 2. Specifications for the Erection of Steel Railway Bridges

The Specifications, Appendix A, are submitted as information. They are the result of careful and extended consideration by the Committee and may be worthy of adoption as a conclusion at this time, but following the practice of the Committee with respect to other important specifications in the past it is desired that they may appear in bulletin form for a year so that we may get the benefit of a trial and discussion by users.

Subject No. 3. Specifications for Movable Railway Bridges

The Specfications, Appendix B, are submitted as a conclusion for printing in the Manual. The statement in the Foreword gives the history of their development. The Committee believes them to be the best specifications for movable bridges available now; and while, from the nature of the subject and the rapidly changing status of the art, they cannot be without faults, their approval and promulgation should not be delayed.

Subject No. 4. Classification of Bridges

Subject No. 5. Specifications for Turntables and Turntable Pits

Subject No. 6. Specifications for Steel Highway Bridges

These three subjects are in the hands of active sub-committees and will be made the principal work of the Committee for next year.

Subject No. 7. Column Tests

Subject No. 8. Electric Welding of Connections in Steel Structures

The Committee recommends the continuation of these two subjects.

Subject No. 9. Rules for Lighting Drawbridges

Subject No. 10. Regulations and Signals for Operation of Drawbridges

The Committee reports progress on these two new subjects and recommends that they be consolidated and reassigned.

Subject No. 11. Outline of Work

The Committee recommends reassignment of the following subjects in the form given:

1. Study the Manual and submit proposed revisions thereof.

2. Submit final specifications for the erection of steel railway bridges.

4. Make final report on the classification of bridges.

5. Continue study and submit report, if practicable, on specifications for turntables and turntable pits.

6. Continue study and report on specifications for steel highway bridges.

7. Continue study and report on column tests.

8. Continue study and report on the electric welding of connections in steel structures.

9. Collaborate with Committee X on rules for lighting and a uniform code of regulations and signals for the operation of drawbridges.

11. Recommend a carefully considered outline of work for the ensuing year.

The following new subjects are recommended:

1. Study the economics of maintenance of railway bridges, including equipment for that purpose.

2. Make rules for field inspection of existing bridges.

3. Make tests and investigations of I-beams connected in groups by diaphragms and bracing, from which conclusions may be drawn, and good practice in designing established.

4. Make tests and study the behavior of bridge pins.

Respectfully submitted,

Committee on Iron and Steel Structures,

O. E. Selby, *Chairman.*

Appendix A

GENERAL SPECIFICATIONS FOR THE ERECTION OF STEEL RAILWAY BRIDGES

For Fixed Spans Less Than 300 Feet in Length

1922

J. A. BOHLAND, *Chairman;*
M. F. CLEMENTS,
THOMAS EARLE,
W. R. EDWARDS,
C. R. FICKES,
J. M. SALMON,
Sub-Committee.

CONTENTS

Article	*Subject*
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2	Work to be done.
3	Drawings to govern.
4	Plant.
5	Plans.
6	Materials.
7	Handling and Storing Materials.
8	Falsework.
9	Masonry.
10 and 11	Bearings and Anchorage.
12	Methods and Equipment.
13	Assembling Steel.
14	Riveting.
15	Bolted Connections.
16	Pin Holes.
17	Deck.
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19	Painting.
20 and 21	Removal of Old Structure and Falsework.
22	Superintendence and Workmen.
23	Interference with Traffic.
24	Company Equipment.
25	Work Train Service.
26	Risk.
27	Inspection.
28	Laws and Permits.

Information to Be Given Bidders

Article

1. A copy of the agreement form.................................... 1
2. A set of general and design plans of the proposed structure, with estimated quantities 5
3. A plan or description of the structure to be replaced, with estimated quantities 2
4. A statement showing the name of, and distance to, the station where the material will be delivered, the nature and amount of traffic, and the side-track and storage facilities to be furnished to the Contractor 6
5. What transportation will be furnished?
6. What work train service will be furnished?......................25
7. Will conductor or pilot service be furnished?....................23
8. What rolling equipment will be furnished?......................24
9. Shall the Contractor furnish and place the falsework?............ 8
10. Shall the Contractor frame and place the timber deck, etc?......17
11. Shall the Contractor place the track and rails and tie-plates?......17
12. Will the old structure be scrapped or re-erected?.................20
13. Shall the Contractor load the falsework material and material from old structure on cars for shipment or pile it at the site?.......20
14. The probable date when the structure will be ready for erection.
15. Shall the bidder furnish a brief description of the method of erection he proposes to follow?
16. Shall the field painting be done by the Contractor?..............19

GENERAL SPECIFICATIONS FOR THE ERECTION OF STEEL RAILWAY BRIDGES

For Fixed Spans Less Than 300 Feet in Length

1922

Definitions of Terms.

1. The term "Engineer" refers to the Chief Engineer of the Company or his subordinates in authority. The term "Inspector" refers to the Inspector or Inspectors representing the Company. The term "Company" refers to the Railway Company or Railroad Company party to the agreement. The term "Contractor" refers to the erection contractor party to the agreement.

Work to Be Done.

2. The Contractor shall erect the metal work, make all connections and adjustments, remove the old structures and falsework and do all work required to complete the bridge or bridges, as covered by the agreement, in accordance with the plans and these specifications.

Drawings to Govern.

3. Where the drawings and the specifications differ, the drawings shall govern.

Plant.

4. The Contractor shall provide all tools, machinery, and appliances, including drift pins and fitting up bolts, necessary for the expeditious handling of the work. The Contractor shall protect the Company against claims on account of patented devices or parts used by him on the work.

Plans.

5. The Company will furnish complete detail plans for the structure or structures to be erected, including shop details, camber diagram, erection diagrams, match-marking diagrams, list of field rivets and bolts, and copy of shipping statements showing a full list of parts and weights.

Materials.

6. The Contractor shall receive, f.o.b. cars, at the siding to be designated in the information to be given bidders, all materials entering into the finished structure.

Handling and Storing Materials.

7. The Contractor shall unload material promptly upon delivery, otherwise he shall be responsible for demurrage charges. Stored material shall be piled securely outside the tracks, and no material shall be placed closer than six feet to the nearest rail. Material shall be placed on skids, above the ground, be kept clean and properly drained. Girders and beams shall be placed upright and shored. Long members, such as columns and

Handling and Storing Materials.

chords, shall be placed on skids near enough together to prevent injury by deflection. The Contractor shall check all material turned over to him against shipping lists and report promptly in writing any shortage or injury discovered. He will be held responsible for the loss of any material while in his care, or for any damage resulting from his work.

Falsework.

8. Unless otherwise provided, the Contractor shall prepare and submit to the Engineer for approval, plans for falsework or for changes in the existing structure necessary for maintaining traffic. The falsework shall be properly designed and substantially constructed and maintained for the loads which will come upon it. Approval of the Contractor's plans shall not be considered as relieving the Contractor of any responsibility. Temporary structures or falsework placed by the Company, if suitable, may be used by the Contractor.

Masonry.

9. The Company will construct the masonry to correct lines and elevations, and will establish the lines and elevations required by the Contractor for setting the steel.

Bearings and Anchorage.

10. Bed plates, bolsters, and shoes shall be set level in exact position. They shall be given full and even bearing by setting them on a layer of Portland cement mortar or dry cement, or by tightly ramming in rust cement after blocking them accurately in position, as directed by the Engineer.

11. The Contractor shall drill the holes and set the anchor bolts, except where the bolts are built into the masonry. The bolts shall be set accurately and fixed with Portland cement grout completely filling the holes.

Methods and Equipment.

12. Before starting work, the Contractor shall advise the Engineer fully as to the method he proposes to follow, and the amount and character of equipment he proposes to use, which shall be subject to the approval of the Engineer. The approval of the Engineer shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment or from carrying out the work in full accordance with the plans and specifications. No work shall be done without the sanction of the Engineer.

Assembling Steel.

13. All parts shall be accurately assembled as shown on the plans and any match-marks carefully followed. The material shall be carefully handled so that no parts will be broken or damaged. Hammering which will injure or distort the work will not be permitted. Bearing surfaces and surfaces to be in permanent contact shall be cleaned just before the members are assembled. Unless erected by the cantilever method, truss spans shall be erected on blocking so placed as to give the trusses proper

Assembling Steel.

camber until all tension chord splices are fully riveted and all other truss connections pinned and bolted. Rivets in splices of butt joints in compression members shall not be driven until the span has been swung. Splices and field connections shall have one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before riveting. Splices and connections carrying traffic during erection shall have three-fourths of the holes so filled.

Fitting up bolts shall be of the same nominal diameter as the rivets, and the cylindrical erection pins shall be $\frac{1}{32}$-inch larger.

Riveting.

14. Riveting preferably shall be done with pneumatic riveters and buckers. Rivets larger than ⅞-inch in diameter shall not be driven by hand. Connections shall be accurately and securely fitted up before the rivets are driven. Light drifting will be permitted to draw the parts together, but drifting to match unfair holes will not be permitted. Unfair holes shall be reamed or drilled. Rivets shall be heated to a light cherry color, and in driving shall be upset to completely fill the holes. Heads shall be full and symmetrical, concentric with the shank, and shall have full bearing all around. They shall be the same shape and size as the heads of the shop rivets. Rivets shall be tight and shall grip the connected parts securely together. No recupping or caulking will be permitted. Rivets shall not be overheated or burned. In removing rivets, the surrounding metal shall not be injured; if necessary, such rivets shall be drilled out. Cup faced dollies, fitting the head closely to insure good bearing, shall be used.

Bolted Connections.

15. In bolted connections, bolts shall be drawn up tight and threads burred so that nuts cannot become loose.

Pin Connections.

16. Pilot and driving nuts shall be used in driving pins. They will be furnished by the Company and shall be returned to the Company on completion of the work. Pin nuts shall be screwed up tight and threads burred so that the nuts cannot become loose.

Deck.

17. Where so specified, the ties, guard timbers, guard rails, fire decking, concrete decking, waterproofing, ballast, and deck planking, and the track rails and tie plates, shall be placed by the Contractor. The timber deck, if untreated, shall be framed and placed in accordance with the Company's plans. The ties shall be framed to give a full and even bearing on the girders and under the rails. The guard timbers shall be dapped and framed to a snug fit over the ties and fastened as shown on the plans. If treated timber is used, the Company will deliver it properly framed to the Contractor. If necessary to do any framing or cutting of treated timber, the resulting surfaces shall be given a brush treatment with wood preservative, as directed by the Engineer. Where concrete decking is used, or waterproofing is required, the specifications therefor will be furnished by the Company.

Misfits.

18. Corrections of minor misfits and a reasonable amount of reaming will be considered as a legitimate part of the erection. Any error in shop work which prevents the proper assembling and fitting up of parts by the moderate use of drift pins, and a moderate amount of reaming and slight chipping or cutting shall immediately be reported to the Inspector, and his approval of the method of correction obtained. The correction shall be made in the presence of the Inspector, who will check the time expended. The Contractor shall render within thirty days an itemized bill for such work of correction for the approval of the Engineer.

Painting.

19. Heads of field rivets shall be painted by the Contractor. This painting shall not be done until the Inspector has examined the rivets and found them satisfactory. The tops of stringers and girders which are to carry ties shall be given one coat of field paint.

If the field painting is to be done by the Contractor, the specifications therefor will be furnished by the Company.

Removal of Old Structure and Falsework.

20. The Contractor shall dismantle the old structure and falsework and load the material on cars for shipment, or pile it neatly at a site immediately adjacent to the tracks, at a convenient elevation for future handling, as directed by the Engineer. When the old structure is of iron or steel and is to be used again, it shall be dismantled without unnecessary damage and the parts match-marked.

21. The Contractor shall remove the piling to the surface of the ground and all debris and refuse resulting from his work, leaving the site in good condition.

Superintendence and Workmen.

22. During the entire progress of the work the Contractor shall have a competent foreman or superintendent in personal charge of the work. Instructions given to the foreman or superintendent shall be considered as given to the Contractor. All work shall be done by skilled, competent workmen.

Interference With Traffic.

23. The Contractor shall conduct his work in such a manner that the track, while in service, will be safe and clear for the passage of trains. Tracks shall be disturbed or removed for the prosecution of the work during such times only as allowed by the Company. While the Contractor is actively engaged in the erection, trains will be required to approach the bridge prepared to come to a stop before crossing and will proceed only on signal. During the time the Contractor operates his equipment on the tracks or has occasion to make the tracks unsafe for the operation of trains, his operations will be in charge of a conductor or pilot who will arrange and control the train movements.

Company Equipment.

24. When the agreement provides that the Company shall furnish equipment to the Contractor, such as flat cars, water cars, bunk cars, etc., the Contractor shall repair all damage to such equipment furnished for his use and return it in as good condition as when he received it.

Work Train Service.

25. When under the contract work train or engine service is furnished the Contractor without charge, the Contractor shall state in his bid the number of days such service will be required. Any excess over the time specified in this bid shall be paid for by the Contractor at the Company's schedule of rates.

Risk.

26. The Contractor shall be responsible for loss of or damage to materials and for all damage to persons or property and for casualties of every description caused by his operations during the progress of the work. Injuries or losses due to events beyond the control of the Contractor shall not be borne by him unless they occurred because of his dilatory methods in handling the work, extending the time beyond the time limit designated in the contract.

Inspection.

27. The work shall be subject at all times to inspection by the Engineer.

Laws and Permits.

28. The Contractor shall comply with Federal, State and local laws, regulations and ordinances, and shall obtain at his own expense the necessary permits for his operations.

Appendix B

SPECIFICATIONS FOR MOVABLE RAILWAY BRIDGES—1922

Burton R. Leffler, *Chairman;*
W. S. Bouton,
M. F. Clements,
O. F. Dalstrom,
Thomas Earle,
R. L. Huntley,
P. G. Lang, Jr.,
Albert Reichmann,
I. L. Simmons,
I. F. Stern,
J. A. L. Waddell,
Sub-Committee.

Foreword

The purpose of the Committee which wrote these specifications was to formulate specific and detailed rules for the design and manufacture of movable railway bridges, as a guide to both the designer and the shop, rather than to confine the specifications to a statement of principles or to limit them to rules defining the duties of the contractor. The intention was to describe the best general practice in the accepted types now in use for standard American and Canadian railways and to advance the causes of good design and workmanship. The requirements of light and branch railways and foreign practice have not been considered.

The specifications in preliminary form were printed in Bulletin No. 204 and in the Proceedings, Vol. 19, and discussions and suggestions were invited. The discussions received were printed in Bulletin No. 228 in 1920. These, together with later written and verbal discussions, were considered by the Committee in the final revision.

SPECIFICATIONS FOR MOVABLE RAILWAY BRIDGES—1922

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(1) PROPOSALS AND GENERAL REQUIREMENTS

101. The General Specifications for Steel Railway Bridges of the American Railway Engineering Association, 1920, with additions and revisions, shall apply to movable bridges except as provided otherwise herein.

Responsibility.

102. Unless otherwise provided, the fabricating contractor shall be responsible for the complete installation of the superstructure and the operation of the moving span as far as pertains to the materials, workmanship, and erection, and the designing of parts and details which are not covered by the proposal plans. The Contractor shall furnish and erect the structure ready for the application of power for its operation and to receive trains.

Time of Opening.

103. The normal time for opening the bridge after the ends are released shall be as specified on the proposal drawings for both the main and the auxiliary powers.

Machinery Drawings.

104. Unless otherwise provided, the Contractor shall furnish an outline drawing of the machinery on which are shown the forces acting on the gear teeth, the twisting moment and the bending moment on shafts, and other information necessary for computing the strength of the machinery parts. The Contractor shall make an assembly drawing and detail drawings of the machinery. These drawings shall be so complete that the machinery parts may be duplicated without reference to patterns, other drawings, or individual shop practice.

Torque Curves.

105. The Contractor shall show by curves the torque to be exerted at the motor pinion as follows:

(a) Torque curves for acceleration and for retardation.

(b) A torque curve for the frictional resistance. The torque for starting friction shall not be combined with the torque for acceleration.

(c) A torque curve for any unbalanced condition of the structure.

(d) A torque curve for the wind loads.

(e) A torque curve showing the greatest resultant combination of resistances acting at one time. The torque curves of the motors under various operating conditions shall be superimposed on this curve.

Weight and Center of Gravity.

106. The Contractor shall determine the weight and (where necessary) the location of the center of gravity of the moving span, including

Proposals and General Requirements.

parts attached thereto; also of the counterweights, including their frame work. These determinations shall be based on weights carefully computed from shop plans. The computations, accompanied by weight bills, shall be submitted to the Company in form for verification.

Houses.

107. The Contractor shall furnish and build the machinery house. The house for the operator and the signal devices shall be built by the Contractor or the Company as may be stipulated.

Signals and Interlocking.

108. The Company will furnish and install the railway signal system, including the master lever and the devices necessary for interlocking the signal system with the moving span. The Contractor shall furnish and install the devices necessary for interlocking the parts of the bridge machinery with each other and for connection to the master lever. The operating machinery and the electrical parts shall be so designed that the signal system may readily be installed and attached.

Warning Lights.

109. The Contractor shall furnish and install (including wiring) on the moving span and piers, navigation lights and other signals required by the United States Government or other authorities, and shall provide suitable means of access to such lights.

Wrenches.

110. Two sets of wrenches to fit heads and nuts of bolts for the machinery shall be furnished by the Contractor.

Defects.

111. If any defects due to faulty workmanship or erection, or defective material, or design for which the Contractor is responsible, are found within one year after the final test and acceptance, the Contractor shall remedy such defects at his own cost. If necessary, the Company may remedy such defects at the expense of the Contractor.

Classification of Parts.

112. The parts of the bridge shall be classified as follows, and unless otherwise stipulated, paid for as indicated:

- (a) Structural steel, by the pound.
- (b) Machinery, by the pound.
- (c) Engines, boilers and tanks, a lump sum.
- (d) Electrical equipment, a lump sum.
- (e) Wire ropes and wire rope attachments, by the pound.
- (f) Houses for machinery and for operators, a lump sum.
- (g) Sheaves for counterweights, by the pound.
- (h) Metal in counterweights, by the pound.
- (i) Concrete, by the cubic yard.
- (j) Timber deck and track, by the linear foot of track.
- (k) Timber walks, by the thousand feet, board measure. Nominal dimensions of timbers to govern.
- (l) Balancing chains, by the pound.

Proposals and General Requirements.

Parts not classified under headings (b) to (l) inclusive, shall be classified under (a), structural steel.

Payment by the pound shall be based on scale weights of the finished material.

113. Parts included in the different classes shall be:

(a) Structural Steel: In addition to the moving span, any parts of rolled or cast steel which can be fabricated by the common shop methods of punching, reaming, drilling, boring, shearing, planing, bending, etc., usual for stationary structures.

Rim girders in swing bridges, segmental girders in rolling bascule bridges and the girders on which they roll, parts supporting the machinery, counterweight frames, counterweight trusses, operating struts, towers, steel framing and plates in houses for machinery and operators, hand rails, stairways, ladders, and specially fabricated track rails, shall be classified as structural steel.

(b) Machinery: Winding drums, tread plates, pedestals, wedge bases, center pivot stands, pistons and their cylinders, eccentrics, pivots, trunnions and their cast supports, shafts, spools, gears, racks, bearings, couplings, clutches, brakes (unless part of the motors), discs, cast sheaves and wheels, rollers, cast roller treads and guides, worm gearing, valves, pins about whose axes the connecting members rotate, screws, wedges, toggles, bridge locks, rail locks, indicators, whistles, cranks, axles, hooks, wrenches, turned bolts attaching machinery parts, and similar parts which require machine shop work and which are not included in any other class.

Machinery parts attached to structural parts shall be weighed separately.

(c) Engines, Boilers and Tanks: Internal combustion engines, steam engines, pumps, compressors, anchor bolts, steam boilers and stacks, air compressor tanks and other tanks, with their fittings and piping.

(d) Electrical Equipment: The switchboard with its attachments and electrical parts beyond (whether on or off the moving span), such as motors, controllers, solenoids, conductors, conduits and their fittings, lamps, blow-outs, cut-offs, circuit breakers, contactors, switches, trolley poles, trolley wheels and contact shoes.

Electrical equipment carrying the current to the switchboard from the source of power will be covered by a separate contract.

(e) Houses for Machinery and Operators: All parts of such houses except steel framing and plates.

(f) Wire Ropes and Wire Rope Attachments: Ropes with their attached sockets, and fastenings of the ropes to the trusses and counterweights, including pins and equalizing devices.

(g) Counterweight Sheaves: Cast or built sheaves, together with their axles and bearings.

(h) Metal in Counterweights: Only cast iron and scrap metal used in counterweights.

(i) Concrete: Concrete and reinforcing bars used in counterweights, and concrete in pockets of column bases and similar places. No deductions shall be made for enclosed metal.

Proposals and General Requirements—Design.

(j) Timber Deck and Track: Placing and permanently fastening the timber deck and track. Unless otherwise specified the Company will furnish the deck and track material and fastenings, except rail-locks, specially fabricated rails, and special devices to hold the deck in place.

(k) Timber Walks: Furnishing and placing lumber in walks, platforms, etc., together with nails, bolts, and other fastenings.

(l) Balancing Chains: Chains and their fastenings used for balancing the counterweight ropes.

(2) GENERAL FEATURES OF DESIGN.

Types.

201. Movable bridges preferably shall be of the following types:

(a) Swing.
(b) Single leaf bascule.
(c) Vertical lift.

The type to be used will be determined by the Engineer. Pin connected trusses shall not be used.

Counterweight.

202. The counterweight shall be sufficient to balance the moving span and its attachments in any position. In vertical lift bridges, the counterweight ropes shall be balanced by chains unless otherwise specified.

Aligning and Locking.

203. Movable bridges shall be equipped with suitable mechanism to align them accurately and to lock them securely in position so that they cannot be displaced either horizontally or vertically under the action of traffic. The operating mechanisms of end lifts and rail locks shall be independent.

Auxiliary Power.

204. Bridges operated by mechanical power shall be equipped with auxiliary power. The auxiliary power shall be hand or mechanical, as determined by the Engineer.

Interlocking.

205. The bridge operating devices shall permit interlocking with the signal system. They shall be so interlocked with each other that the operations, both for opening and closing the bridge, must be performed in a predetermined order.

Insulation of Track.

206. The connections of parts in contact with the track shall be such as to prevent all possibility of short circuiting of track signals.

Houses for Machinery and Operators.

207. If mechanical power is to be used for operating the bridge, a suitable house shall be provided for the machinery and the operator. The house shall be large enough for easy access to all machinery. The

General Features of Design.

house shall be fireproof and weatherproof. There shall be at least one window in each side of the house.

The floor shall be built of concrete. It shall be smoke tight and have a non-slip surface.

If the operator is not located in the machinery house, or if the bridge is hand operated, a house shall be provided for him. The type of construction shall be the same as that specified for the machinery house, except that for hand-operated bridges with the house located off the bridge structure, fully fireproof construction will not be required.

Provision shall be made for the heating apparatus to be installed by the Company in the operator's house.

If stipulated, a 5-ton capacity hand operated overhead traveling crane shall be installed in the machinery house.

Stairways and Walks.

208. Metal stairways, platforms, and walks with railings shall be provided, for access to the operator's house, machinery, trunnions, counterweights, lights, bridge seats, and similar parts. Ladders may be installed only where stairways are not feasible. In vertical lift bridges, ladders and walks shall be installed to give access to the moving span in any position from either tower. Hand railings shall be made of gas pipe not less than 1½-inch size. Stairways and ladders shall be of metal. The treads may be channels filled with concrete.

Materials Used.

209. Materials in machinery and similar parts shall be as follows:

Rolled Steel or Forged Steel: For trunnions, shafts, axles, bolts, nuts, keys, cotters, pins, screws, worms, piston rods, and crane hooks.

Shafts up to 6 inches in diameter may be either rolled or forged; shafts larger than this shall be forged. Shafts larger than 3½ inches in diameter shall not be cold rolled.

Forged Steel or Cast Steel: For rim girder tread plates, levers, cranks, connecting rods, and rollers.

Forged Steel: For pinions and equalizing levers.

Cast Steel: For pivot stands, couplings, wedges, wedge bearings, trailing wheels, end shoes, racks, tracks, winding drums, gears, brake wheels, sheaves on lift bridges, trunnion bearings and shaft bearings and hangers. Large sheaves may be built of structural steel and cast steel.

Tool Steel: For parts which require hardening or oil tempering, such as pivots, friction rollers, ball bearings and springs.

Phosphor-Bronze: For pivot discs, worm wheels, linings of the trunnion bearings of bascule and lift bridges, linings of other large bearings carrying heavy loads, and such gears and nuts as are required to be of bronze.

Phosphor-Bronze, Bronze, or Babbitt Metal: For the linings of journal bearings and of other rotating or sliding parts.

General Features of Design.

Cast Iron may be used for eccentrics, cylinders, pistons, fly-wheels, certain shaft bearings described below, journal boxes, and parts of motors which are usually made of cast iron. In power operated bridges, the permission to use cast iron shaft bearings applies only to line shaft bearings carrying the weight of the shafting only. Cast iron shall not be used for couplings, for trunnion supports of bascule or lift bridges, or in the pivots of swing bridges.

The balancing chains, which are hung below the counterweights in vertical lift bridges, shall be made of cast iron links connected by steel pins in cored holes.

Type of Center.

210. The type of center to be used in swing bridges will be determined by the Engineer.

Center Bearing.

211. Center bearing swing bridges shall be so designed that when the bridge is swinging, the entire weight of the moving span is carried on a center pivot, and when the bridge is closed, the trusses rest at the center on wedges. Adjustment for height shall be provided.

Rim Bearing.

212. The load on the rim girder of a rim bearing or combined rim- and center bearing swing bridge shall be distributed equally among the bearing points. The bearing points shall be spaced equally around the rim girder.

Rigid struts shall connect the rim girder to a center pivot firmly anchored to the pier. A strut shall be attached to the rim girder at each bearing point, and at intermediate points when required. No fewer than eight struts shall be used in any case.

The rim girder shall be so designed that the load will be properly distributed over the rollers. For calculating stresses in the girder, the loads shall be assumed to be distributed equally to all rollers. The span length shall be taken as the developed length of the girder between adjacent bearing points. This part of the girder shall be considered fixed at both ends. The girder shall be designed in accordance with the requirements for plate girders.

The lower track shall be strong enough to distribute the load on the rollers uniformly over the masonry.

Combined Bearing.

213. In a combined rim- and center bearing swing bridge, a definite portion of the load, not less than 15 per cent., shall be carried to the center by radial girders attached rigidly to the center and to the rim.

Shear Over Center.

214. In swing bridges having a center truss panel, this panel shall be so designed that shear will not be carried past the center. The web members of such panel shall be strong enough, however, to make the bridge secure against longitudinal wind pressure when it is open.

(3) LOADS, UNIT STRESSES, AND PROPORTIONING OF PARTS

Stresses in Swing Bridges.

301. The stresses in trusses or girders of swing bridges continuous on three or four supports shall be calculated for the bridge in the following conditions:

1. Bridge open, or closed with ends just touching.
2. Bridge closed with ends lifted.

The computation of stresses shall be divided into the following cases:

Case I. Condition 1, dead load.

Case II. Condition 2, dead load, ends lifted to give positive reaction equal to one and a half times the maximum negative reaction of the live load and impact plus 50 per cent. of their sum.

Case III. Condition 1, live load on one arm as a simple span.

Case IV. Condition 2, live load on one arm, bridge as a continuous girder.

Case V. Condition 2, live load on both arms, bridge as a continuous girder.

The following combinations of these cases shall be used in determining the maximum stresses:

Case I alone.
Case I with Case III.
Case I with Case V.
Case II with Case IV.
Case II with Case V.

The stress sheet shall show the stresses in the different members for each of the foregoing cases, together with the combinations which give the greatest positive and negative stresses in each member.

In computing the live load stresses, the live load shall be considered as applied, either continuously or in detached parts, in such a manner as to produce the maximum stresses.

Impact.

302. Stresses in structural parts which vary with the movement of the span (as in the case of a bascule bridge) shall be increased 20 per cent. as an allowance for impact. This impact allowance shall not be combined with the live load stresses.

Stresses in structural parts caused by the machinery or by forces applied for moving or stopping the span shall be increased 100 per cent. as an allowance for impact.

The end floor beams of the moving span and the adjacent floor beams of the fixed spans shall be proportioned for a concentrated load of 75,000 lb. on each track, in addition to the specified live load and impact.

End Ties.

303. The first two ties of the moving span and of the adjacent ends of the fixed spans shall be supported throughout their length so that they will not be subjected to bending. The supports for these ties, if other than end floor beams, shall be proportioned for a concentrated load of 75,000 lb. on each track plus 150 per cent. impact.

Loads, Unit Stresses and Proportioning of Parts.

Reversal of Stress and Secondary Stresses.

304. Structural members and their connections, subject to reversal of stress during the movement of the span, shall be proportioned as follows: Determine the resultant tensile stress and the resultant compressive stress, and increase each by 25 per cent. of the smaller; then proportion the member to resist either increased resultant stress.

Secondary stresses occurring in connection with reversal of stress, and those in trusses of unusal form, shall be computed, and provided for in proportioning.

End Lift Reactions.

305. The end lifting machinery of swing bridges shall be proportioned to exert an uplift equal to the maximum negative end reaction of the live load and impact plus 50 per cent. of their sum.

The end bearings shall be proportioned for the maximum positive end reaction including impact.

The center wedges and supports shall be proportioned for the reaction of the live load and impact.

Rollers.

306. The rollers of rim bearing or combined rim- and center bearing swing bridges shall be proportioned for the dead load stresses when the bridge is swinging, and for the dead and live load and impact stresses when the bridge is closed.

In computing the load on the rollers, the rim girder shall be considered as distributing the load uniformly over a distance equal to twice the depth of the girder, back to back of flange angles. This distance shall be taken as symmetrical about the vertical through the point of application of the concentrated load.

Wind Load and Ice Load.

307. In proportioning the members and determining the stability of the moving span and the towers of bascule bridges and vertical lift bridges when the span is in the open position, the wind pressure shall be assumed as 15 lb. a square foot, applied to the exposed surface of the floor and the two trusses as seen in elevation.

In determining the stability of swing bridges when open, the wind pressure shall be assumed as 2½ lb. a square foot acting on the horizontal projection of one arm.

In swing spans, the transverse balance wheels and their axles, bearings, and brackets shall be designed for an overturning wind pressure of 10 lb. a square foot of surface of the floor and the two trusses as seen in elevation.

For open deck bridges, the area of the floor exposed to wind and ice shall be taken as 85 per cent. of the area of a quadrilateral, whose width is the distance center to center of trusses and whose length is that of the floor of the span. For bridges with solid floors, or with footwalks, the actual exposed floor surface shall be taken.

Loads, Unit Stresses and Proportioning of Parts.

In proportioning the members and determining the stability of the bridge when closed, the assumed wind loads shall be in accordance with the General Specifications for Steel Railway Bridges of the American Railway Engineering Association.

308. In proportioning the machinery and determining the power required for operation, the loads shall be assumed as applied in the following manner:

For bascule and unequal arm swing bridges, the machinery shall be proportioned to hold the span in any position with a wind load of 15 lb. a square foot on any vertical projection of the open bridge. In proportioning the machinery for this condition, the stresses specified herein may be increased one-half.

The machinery shall be proportioned and power provided to move the span under the following conditions:

(A) In the normal time for opening:
   1. Bascule bridges and vertical lift bridges against frictional resistances, inertia, and a wind load of 2½ lb. a square foot on the floor area, acting normal to the floor.
   2. Swing bridges against frictional resistances, inertia, and a wind load of 2½ lb. a square foot of the vertical projection of one arm.

(B) In one and one-half times the normal time for opening:
   Bascule bridges and vertical lift bridges with an ice load of 2½ lb. a square foot of floor area in addition to the loads specified in (A).

(C) In twice the normal time for opening:
   Bascule bridges and unequal arm swing bridges against frictional resistances, inertia, a wind load of 10 lb. a square foot of any vertical projection and an ice load of 2½ lb. a square foot on the floor area.

Machinery Resistances.

309. In calculating the resistances to be overcome by the machinery, the resisting forces shall be reduced to a single force acting between the pinion and the operating rack, or in the operating cable. In determining this force, the following coefficients shall be used:

	For Starting	For Motion
For trunnion friction:		
a. One or more complete rotations........	0.135	0.09
b. Less than one complete rotation........	0.18	0.12
For friction on center discs	0.15	0.10
For rolling friction of bridges having rollers with flanges, or built-up segmental girders..	0.009	0.006
For collar friction at ends of conical rollers....	0.15	0.10
For bending of wire ropes, for each sheave, the coefficient of direct tension in rope........	$\frac{d^2}{3D}$	$\frac{d^2}{3D}$
($d =$ diam. of rope in inches, $D =$ diam. of sheave in inches).		
For rolling friction of solid cast rollers without flanges:		
a. In contact with one surface only....	$\frac{3}{200r}$	$\frac{3}{200r}$
b. In contact with two surfaces............	$\frac{3}{100r}$	$\frac{3}{100r}$

($r =$ the radius of the roller in inches.)

Loads, Unit Stresses and Proportioning of Parts.

In designing the machinery for holding the span against the 15 lb. wind pressure specified, and for computing braking effect, 0.4 of the above mentioned coefficients for motion shall be used. Rope stiffness, solid roller friction, and machinery friction shall be disregarded.

For sliding friction between plane surfaces intermittently lubricated (such as guides on tower posts), the coefficient of friction shall be taken as 0.08.

Machinery Losses.

310. In computing the machinery losses between the operating rack, or the operating rope, or a similar point, and the prime mover, the following coefficients shall be used:

For journal friction	0.05
For efficiency of any pair of gears, journal friction not included:	
Spur gears	0.98
Bevel gears, collar friction included	0.90
Efficiency of worm gearing, angle of thread 20 deg. or more, collar friction included	0.60

Brakes.

311. The machinery, including the brake mechanism, shall be capable of resisting the stresses caused by stopping the bridge in five seconds. The braking capacity shall be sufficient to stop the bridge in ten seconds. The coefficient of friction for braking shall be taken at 0.25. If practicable, the pressure per square inch on the rubbing surface of the brake shall not exceed 25 lb.

If brakes act through the machinery, the unit stresses produced in the machinery by braking shall not exceed 1½ times those allowed for the normal torque of the prime mover. However, for the braking mechanism and for parts which receive stress only through braking, the unit stresses shall not be increased.

Unit Stresses.

312. Structural parts shall be proportioned by the General Specifications for Steel Railway Bridges of the American Railway Engineering Association.

The following unit stresses in pounds per square inch shall be used for machinery and similar parts in which main stresses are not increased by impact:

Material	*Tension*	*Compression*	*Fixed Bearing*	*Shear*
Rolled or forged steel	9,000	$9{,}000 - 40\frac{l}{r}$	13,000	6,500
Stress in extreme fibers of trunnions	13,000	13,000		
Cast steel	7,000	$8{,}000 - 35\frac{l}{r}$	10,000	5,000
Phosphor-bronze	6,000	6,000		4,500
Cast iron	1,500	8,000*	8,000	2,000
Keys			9,000	5,000

*For struts whose $\frac{l}{r}$ is 20 or less.

Loads, Unit Stresses and Proportioning of Parts.

For stresses which are reversed at the rate of ten or more times a minute, two-thirds of the above mentioned unit stresses shall be used.

Bearing Pressures.

313. The following maximum bearing pressures, in pounds per square inch, for rotating and sliding surfaces shall be used:

a. For intermittent motion with speed not exceeding 100 ft. per minute:

Pivots of swing bridges, hardened tool steel on phosphor-bronze discs	3,000
Trunnion bearings, structural steel on phosphor-bronze	1,500
Wedges, cast steel on cast steel or structural steel	500
Screws which transmit motion (on projected area of thread)	200

b. For speeds exceeding 100 ft. per minute:

Hardened steel on hardened steel	2,000
Hardened steel on bronze	1,500
Structural steel on bronze	600
Structural steel on babbitt metal or brass	400
Structural steel on cast iron	400
Cross-head slides (speed not exceeding 600 ft. per minute)	50

Journal and Pivot Bearings.

314. The pressure on pivots or step bearings for vertical shafts, and on journals, shall not exceed:

On pivots, $p=\frac{60{,}000}{nd}$, but not more than 900.

On journals $p=\frac{250{,}000}{nd}$, but not more than 600.

On collars, $p=\frac{50{,}000}{nd}$, but not more than 200.

p=pressure in pounds per square inch.

n=number of revolutions per minute.

d=diameter of pivot or journal or mean diameter of collar in inches.

For crank pins and similar joints with alternating application and release of pressure, the bearing values given by the foregoing formulas may be doubled.

Pressure on Rollers.

315. The permissible pressure in pounds a linear inch of rollers shall be:

For rollers in motion: (d not to exceed 64 in.)	
Cast iron	$200d$
Cast steel	$400d$
Structural steel	$300d$
Tool steel	$800d$
Hardened tool steel	$1000d$
For rollers at rest: (d not to exceed 28 in.)	
Rolled or cast steel	$600d$

(d=diameter of roller in inches.)

The foregoing values are for rollers and bearing surfaces of like materials. If the rollers and bearing surfaces are of unlike materials, the lower value shall be used.

Loads, Unit Stresses and Proportioning of Parts.

Wire Ropes.

316. The total unit tension in counterweight ropes shall not exceed one-fifth of the specified unit ultimate strength of the rope, nor shall the unit tension from the direct load only exceed one-tenth of the specified unit ultimate strength. For operating ropes, the corresponding limits shall be one-third and one-sixth.

317. If a wire rope is bent over a sheave, the bending stress and permissible load on the rope shall be calculated as follows:

Let P = the permissible load on rope, in pounds.
K = unit stress due to bending in extreme fiber of largest individual wire.
E = modulus of elasticity = 28,500,000.
a = cross-sectional area of rope in square inches.
d = diameter of largest wire in inches.
D = diameter of sheave, center to center of rope, in inches.
S = greatest unit tension allowable.
L = angle of helical wire with axis of strand.
B = angle of helical strand with axis of rope.
c = diameter of rope.

Then $$K = \frac{Ed \cos^2 L \cos^2 B}{D} \qquad (1)$$

$$P = a\left[S - \frac{Ed \cos^2 L \cos^2 B}{D}\right] = a\left[S - \frac{0.9Ed}{D}\right] \qquad (2)$$

For rope having 6 strands of 19 equal wires each,

$$P = a\left[S - \frac{1700000c}{D}\right] \qquad (3)$$

assuming $d = \frac{c}{15}$.

For haulage rope, 6 strands of 7 wires each, $d = \frac{c}{9}$.

318. If a rope is in contact with a small sheave over a short arc (50 deg. or less), the actual radius of curvature of the rope may be greater than that of the sheave.

Let R = the actual radius of curvature of the rope.
θ = the angle between the directions of the rope.
W = pull on individual wire (equal to P divided by the number of wires if all wires are of equal diameter).

Then $$R = \frac{d^2}{4.25 \cos\frac{\theta}{2}}\sqrt{\frac{E}{W}}$$

If R is greater than the radius of the sheave, $2R$ should be used in place of D in formulas (1), (2) and (3).

Loads, Unit Stresses and Proportioning of Parts—Design.

Shafts.

319. Circular shafts, trunnions and axles shall be proportioned by the following formulas:

$$f = \frac{32}{\pi d^3}\left[\frac{3}{8}M + \frac{5}{8}\sqrt{M^2 + T^2}\right]$$

$$S = \frac{16}{\pi d^3}\sqrt{M^2 + T^2}$$

f = unit extreme fiber stress in tension or compression.
S = unit shear.
d = diameter of shaft at the section considered.
M = simple bending moment computed for the distance center to center of bearings.
T = simple twisting moment.

In the case of reversal at the rate of ten or more times a minute, increase M one-half. In this case, f shall not be reduced on account of reversal.

If a shaft, trunnion, or axle has one keyway at the section where the maximum stresses occur, f and S shall be considered to be increased by one-sixth; if two keyways, by one-fourth.

Excess Loads.

320. The machinery parts shall be designed for the loads specified in Art. 308, using the unit stresses herein given. For the stresses caused by the motor when exerting twice the greatest normal torque, twice the normal unit stresses may be used.

End Lift Machinery.

321. In designing the machinery parts for the end lifts of swing bridges, the same methods specified for the machinery actuating the moving span shall be used.

Impact.

322. Impact in trunnions, wire ropes, wire rope attachments, and machinery parts is allowed for in the foregoing unit stresses.

(4) DETAILS OF DESIGN.

Rail End Connections.

401. Designs for rail end connections will be furnished by the Engineer. If the connections are of the sliding rail lock type, the ends of the bridge rails shall be fixed, cut square, and connected with the approach rails by sliding sleeves or joint bars, to carry the wheels over the openings between the rail ends. The distance from the center of the track to the inside of the rail lock wheel tread shall be not less than 2 feet 6 inches, and not more than 2 feet 6½ inches, the heads of the rails being planed off on the outside if necessary. At the heel end of bascule bridges, the sliding locks shall be on the approach. Sliding rail locks, if power operated, shall have not less than 2½ horse-power per track for each end of the bridge (but not less than 5 horse-power at each end of the bridge).

Details of Design.

Rim Girders.

402. Rim girders shall be provided with stiffeners with fillers on both sides of the web at points of concentrated loading. These stiffeners shall fit close against both flanges. The distance between adjacent intermediate stiffeners shall not exceed two feet. On rim girders exceeding five feet in depth, alternate intermediate stiffeners may extend only half the depth of the girder, unless required to be of full depth to stiffen the web. The thickness of the outstanding legs of stiffener angles shall be not less than one-eighth of their width. The tread plate for the rollers shall be securely fastened to the rim girder and shall be from 2 to 3 inches thick, depending on the weight of the bridge. The rim girder flange angles shall be not smaller than 6 inches by 4 inches by ¾-inch.

Centering and Locking Devices.

403. Bascule and vertical lift bridges shall be provided with self-centering and seating devices at the free end. There shall be a locking device for each truss to force down and hold the free end.

Air Buffers.

404. Power operated skew swing bridges, bascule and vertical lift bridges shall be provided with air buffers; for single track bridges, one at the free end of bascules, and one at each end of vertical lifts. For multiple track bridges, twice the number shall be used. The inside diameter of the cylinder shall be not less than 12 inches, and the travel of the piston not less than 24 inches. There shall be three cast iron packing rings for each piston.

End Lift and Center Wedges.

405. The end lifting apparatus of swing bridges shall be arranged to center the bridge accurately when closed unless a separate device is used to center the bridge. The end lift and center wedges shall be so designed that the action of the moving load cannot cause displacement of the end supports and wedges in case of failure or disconnection of the mechanism which actuates the end lift. The end lifting apparatus and center wedges shall be so designed as to permit adjustment. The center and end wedges may be operated by the same mechanism.

Counterweights.

406. Counterweights usually shall be of concrete supported by a steel frame. The concrete may be inclosed in a steel box. Counterweights shall be so made as to be adjusted easily for variations in the weight of the moving span. Usually this shall be done by adding or taking off properly located cast iron or concrete blocks. Space for 3½ per cent. under and 5 per cent. above the calculated weight shall be provided. Movable blocks to the amount of 3½ per cent. shall be provided.

In vertical lift bridges the counterweights shall clear the track rails by not less than 3 feet when the span is fully opened. The counterweight ropes shall be assumed to stretch two per cent. of their figured length.

Details of Design.

407. In vertical lift bridges, counterweights hung by ropes shall be divided into parts so that each part will be hung by not more than sixteen ropes. The ropes of each group shall be attached to the part by an equalizer.

Pockets in Counterweights.

408. Pockets in counterweights shall be provided with drain holes not less than six inches in diameter. The pockets shall be covered. The cover, its fastenings and frame shall be of metal.

Concrete.

409. Concrete, unless otherwise specified, shall be composed of 1 part of Portland cement, 2½ parts of sand and 5 parts of stone. Otherwise the concrete shall conform to the specifications of the Company. In counterweights, steel punchings or scrap metal may be used to increase the weight. The punchings or metal shall be placed in layers and grouted with mortar composed of 1 part of cement and 2 parts of sand; the maximum available weight shall not exceed 315 pounds a cubic foot. If the counterweight containing such mixture of metal or punchings revolves about a horizontal axis, it shall be retained in place by a surrounding steel box, or by walls of concrete.

Concrete counterweights of the revolving type shall be poured continuously if practicable.

For ascertaining the weight of the concrete, test blocks having a volume of one cubic foot shall be cast at least thirty days before concreting is begun. The consistency of the concrete in the test blocks shall be the same as that of the concrete in the counterweight.

Diameter of Sheaves.

410. For counterweight ropes, the diameter of the sheave (measured from center to center of ropes) shall be not less than 75 times the diameter of the rope; 90 times is preferable. For operating ropes, the diameter of the drum shall be not less than 45 times the diameter of the rope; 50 times is preferable.

Disc Bearings.

411. Center bearing bridges shall revolve on disc bearings. Disc bearings shall consist of two discs, one of phosphor-bronze and one of hardened steel.

Center Pivots.

412. Center pivots shall be so designed that the discs may be taken out and replaced while the bridge is closed, without interfering with the operation of trains over the bridge. The discs shall be so anchored that sliding will take place only at the surfaces of contact of the discs.

Balance Wheels.

413. For power operated center bearing bridges, no fewer than eight wheels, running on a circular track, shall be provided to limit the tilting of the bridge and to carry the wind pressure to the track while the bridge

is swinging. The balance wheel bearings shall be adjustable for height, preferably by shims between the superstructure and the seats of the bearings. For short, single track, hand operated bridges, four wheels may be used.

Wheels shall be fastened to the trunnions by keys.

Rack and Track.

414. The rack and track of swing bridges shall be made in sections, preferably not less than 6 feet long. The track shall be deep enough to insure good distribution of the balance wheel or roller loads to the masonry, but in no case shall the depth for rim bearing bridges be less than four inches. If a cast track is used and the loads are light, as in center-bearing bridges, the rack and track segments preferably shall be cast in one piece. In rim-bearing bridges, the rack shall be cast separate from the track, so that the parts may be easily removed for repairs. The joints in the rack and track shall be staggered. The track shall be anchored to the masonry by bolts not less than 1½ inches in diameter, extending at least 12 inches into the masonry, and set in Portland cement mortar or grout. The track of hand operated center-bearing bridges shall have an ample number of anchor bolts so that the mortar or grout in which they are set will not be crushed by the tractive force developed when turning the bridge. When center bearing bridges are operated by mechanical power, the track shall be anchored down by bolts and the tractive force developed when turning the bridge shall be taken by lugs extending from the bottom of the track downward into the masonry and set in cement mortar, grout or concrete.

Segmental Girders and Track Girders.

415. The flanges of the segmental girders and the track girders of rolling bridges shall be symmetrical about the central planes of the webs. The central planes of the webs of the segmental girders shall coincide with the corresponding central planes of the webs of the track girders. That part of the outstanding leg of a flange angle which is beyond the outside face of the vertical leg shall not be considered as bearing area. The width of contact between the segmental girder and the back of the tread plates shall be equal to the corresponding width of contact in the track girder.

Rollers and wheels with full circumference shall be rolled, forged or cast in one solid piece.

The treads attached to the segmental girders and the track girders shall be steel castings and shall not be considered as part of the flange of these girders. There shall be open joints between adjacent castings. For any position of the bridge the treads shall be considered as pedestals distributing the line bearing pressure between them to the girders. To effect this distribution properly, the castings shall be proportioned as to depth, width and unit stresses as a cast base under a column.

Details of Design.

The permissible load in pounds a linear inch of line bearing between treads shall be 3200 $\sqrt{d}$ (d being the diameter of the roller in inches). The bearing of metal on metal, considering the area covered by planes 45° from the perpendicular from point of contact, shall not exceed 13,000 lb. a square inch. The material in the tread castings at the joints shall fulfill the above requirements. The surfaces of contact between the segmental girder and the tread castings preferably shall be plane surfaces. The loads considered in this paragraph shall include 20 per cent. impact as provided in Article 302.

Machinery Design.

416. The machinery shall be simple and substantial in design, and easily erected, inspected, adjusted and taken apart. The fastenings shall be adequate to hold the parts in place under all conditions of service. If practicable, the machinery shall be mounted on a self-contained cast steel frame or base; otherwise on a rigid structural steel support.

Location of Machinery.

417. The location of the machinery shall be such as to allow easy access and room for ample size of supporting parts. In bascule bridges, the machinery preferably shall be on the stationary part.

Bearings.

418. Bearings shall be placed close to the points of loading. The bearings for mating bevel gears shall be made in one solid piece. The length of a bearing shall be not less than the diameter of the journal.

419. Journal bearings shall be of the divided type. The cap shall be recessed into the base and fastened by turned bolts recessed into the base. Cap screws for this fastening will not be accepted. Nuts shall be hexagonal. Check nuts shall be provided. The holes in the supports shall be ¼ inch smaller than the bolt, for subsequent reaming. The nuts of bolts shall bear on finished bosses or spot faced seats. The bearings shall be designed to facilitate cleaning. Trunnion bearings shall have outlets for flushing.

420. Provision shall be made for alining shafts that cannot be fitted in the shop.

421. In swing bridges, the main pinion shaft bearings shall be designed with enough shims to provide for overrun or underrun in the diameter of the rack as fitted up in the shop, and, if feasible, the bearings shall be shipped with the necessary shims in position. Provision shall be made for adjustment for wear and in height of all important bearings, and adjustment of their caps, by means of liners or some other effective device, where it is obvious that such adjustment will be necessary.

Linings.

422. Bearings for main pinion shafts and for shafts carrying heavy loads shall have phosphor-bronze linings; for other cast steel bearings, the lining may be of bronze or babbitt metal. The lining shall be provided with an effective device to prevent it from rotating. The force tending to cause rotation shall be taken as one-sixth of the load on the trunnion or

Details of Design.

bearing and as acting at the outer circumference of the lining. There shall be ⅛ inch clearance between the lining of the cap and the lining of the base. The inside longitudinal corners of the lining shall be rounded except for a distance of ⅜ inch from each end. Cast iron bearings need not be lined.

Main Pinion Shaft Bearings.

423. When the tooth load on the rack requires difficult connections of the rack to the masonry, two or more pinions shall be used. When two pinions are used, they shall be placed diametrically opposite. When four pinions are used they shall be placed in pairs diametrically opposite.

The brackets that support the rack pinions shall be of ample strength for the maximum pinion force. They shall be in a single piece supporting both bearings of the pinion shaft. They shall be thoroughly braced and rigidly attached to the rim girder or the superstructure.

The pinion shaft bearings preferably shall be cast in one piece. The bearings shall be provided with caps so that the pinion shaft can be taken out without removing the bearings or the bracket.

Means shall be provided for holding the pinions against movement along the shaft.

Lubrication.

424. Provision shall be made for effective lubrication of sliding surfaces. Lubricating devices shall be easily accessible.

Screw compression tell-tale grease cups shall be provided for journal bearings. If the journals are not accessible, the cups shall be connected by pipes. Grease ducts shall be so located that the lubricant will tend to flow by gravity toward the bearing surface. Grooves shall be provided wherever necessary for the proper distribution of the lubricant.

The grooves for large trunnion bearings shall be cut in the trunnion. They shall be straight, parallel with the axis of the trunnions, and no fewer than three. They shall be so located that the entire bearing surface of the lining will be swept by the lubricant in one movement of opening or closing the bridge. The bottom of the groove shall be rounded. The corners shall be rounded to a ¼-inch radius. The size shall be such that a $\frac{3}{16}$-inch wire will lie wholly within the groove. The grooves shall be accessible for cleaning with a wire.

In disc bearings straight grooves shall be cut in the upper one of the two rubbing surfaces in contact. The grooves shall be not less than one-fourth inch in width and depth and the corners shall be rounded to a radius not less than half the width of the groove. The corners at the bottom of the grooves shall be filleted; there shall be no sharp corners.

Covers.

425. Dust covers shall be provided wherever necessary to protect the sliding and rotating surfaces and prevent dust from mixing with the lubricant.

Details of Design.

If gears or sheaves are located where falling objects may foul them, they shall be protected by metal covers easily removed.

Counterweight sheave rims shall be covered to protect them from the weather.

Shafts.

426. For shafts supporting their own weight only, the unsupported length of the shaft shall not exceed $L = 80 \sqrt[3]{d^2}$ in which: L = length of shaft between bearings in inches; d = diameter of shaft in inches.

Line shafts connecting the machinery at the center of the bridge with that at the ends shall be designed to run at fairly high speed, the speed reduction being made in the machinery at the end.

Shafts transmitting power for the operation of the bridge, and shafts four feet or more in length forming part of the operating machinery of rail locks and bridge locks, shall be not less than 2½ inches in diameter.

Journals on cold rolled shafting shall not be turned down.

Mechanical devices using power transmitted by compressed air may be used for the operation of center wedges, end lifts, centering devices and sliding rail locks.

Collars.

427. Collars shall be provided wherever necessary to prevent the shaft from moving lengthwise. There shall be at least two set screws, 120 degrees apart in each collar. If a shaft or trunnion receives a longitudinal force, there shall be a thrust bearing to prevent longitudinal movement.

Longitudinal Thrust.

428. Wheels and similar parts shall be securely fastened, to prevent longitudinal movement, by set screws through the hub or by clamps around the shaft. The hubs of bevel gears shall bear against the shaft bearing. Provision shall be made to hold bevel gears and worm wheels against movement along the shaft.

Step Bearings.

429. The bearing ends of vertical shafts running in step bearings shall be of tool steel, and shall bear on bronze discs.

Shaft Couplings.

430. Shafting liable to be thrown out of line by the deflection of the supporting structure shall be made in non-continuous lengths connected by claw couplings. These couplings shall be fitted together accurately, but with allowance for a slight angular motion without bending the shaft. Each length of shafting of this kind preferably shall rest in not more than two bearings. The couplings shall be close to the bearings.

Couplings in shafting other than the above mentioned shall be of the flanged or the split muff type. The bolt heads and nuts shall be seated in recesses, or protected by flanges. The couplings shall be cylindrical. They shall be keyed to the shaft.

Details of Design.

Gear Teeth.

431. Gear teeth shall be of the involute type. The angle of obliquity shall be 20 degrees. The radial height of the tooth above the pitch line shall not exceed 0.32 of the circular pitch.

The width of face of a spur gear tooth shall be not less than 1½ times the circular pitch. For pitch circle speeds not exceeding 600 feet a minute, the width shall be not more than three times the circular pitch. The width of face of a bevel gear tooth shall not exceed one-third of the slant height of the pitch cone, or three times the pitch at the middle section.

The circular pitch of gear wheels (other than motor pinions) transmitting power for moving the span shall be not less than 1¼ inches. For the pinion engaging the operating rack, the pitch shall be not less than two inches.

No pinion shall have fewer than twelve teeth and where feasible fifteen. No pinion with stub teeth shall have fewer than fourteen.

Strength of Gear Teeth.

432. In spur gears and bevel gears, the load transmitted shall be taken as applied on one tooth only; in worm wheels, as being equally distributed between two teeth.

A standard shaped tooth is one having the following characteristics: (a) The profile is a 20 degree involute curve; (b) the radial height outside of the pitch circle is closely 0.32 of the circular pitch; (c) the thickness of the tooth at the pitch circle is half of the circular pitch.

The allowable load on cut gear teeth of standard shape shall conform to the following formula:

$$W = psf\left[0.154 - \frac{0.912}{n}\right]\frac{600}{600+V}$$

W = the allowable load on the tooth in pounds.

s = the permissible stress in pounds a square inch:

= 9,000 for bronze.

= 16,000 for steel.

f = width of face of tooth in inches.

p = circular pitch in inches.

V = velocity of pitch circle in feet a minute.

n = the number of teeth in the gear.

The allowable load on machine molded teeth shall conform to the foregoing formula, taking $s = 14{,}000$ for cast steel.

For teeth not of standard shape, the following formula shall be used:

$$W = \frac{sft^2}{6r} \times \frac{600}{600+V}$$

t = thickness of tooth in inches at section under consideration.

r = radial height of tooth in inches measured from section where t is taken.

The other symbols are defined as in the formula for standard teeth.

For calculating the teeth of bevel gears, the middle section of the tooth shall be taken.

Details of Design.

Teeth to Be Cut.

433. The teeth of gears transmitting power for the operation of the bridge, bevel gears, and wheels in the gearing of any motor, shall be machine cut.

Equalizing Devices.

434. In power operated swing bridges there shall be no fewer than two rack pinions. The shafts of these pinions shall be connected by a device which will equalize the turning forces at the pinions.

There shall be devices on bascule and vertical lift bridges to equalize the forces at the pinions.

Worm and Screw Gearing and Cams.

435. In worm gearing and screw gearing for transmitting power (except for end lifts of swing bridges), the angle of the thread shall be not less than 20 degrees. For end lifts and wedges, the angle of the thread shall be small enough to prevent reverse motion under load. The worm shall run in oil. There shall be bronze collars at the ends of the screw in screw gearing, and on the worm wheel axle in worm gearing, to take the end thrusts. The wheel in worm gearing and the nut in screw gearing shall be of bronze. Screws shall have square threads. Worm wheels shall have no fewer than 30 teeth. Worm and wheel gearing shall be enclosed in a cast iron casing. The worm shall be below the wheel.

Except for end lifts of swing bridges, worm and screw gearing preferably shall not be used for transmitting power.

Cams and similar devices transmitting power by line or point contact shall not be used.

Springs.

436. Springs preferably shall not be used to actuate any moving part. For electrical parts, preference will be given to those having the fewest springs.

Keys and Keyways.

437. Keys for fastening machinery parts to shafts shall be gib head keys, tapered if practicable; if not practicable, parallel faced. The keys shall be sunk in keyways in both hub and shaft.

The taper of the key shall be ⅛ inch per foot. The width shall be one-fourth of the diameter of the shaft. The height at the middle of the tapered length shall be three-fourths of the width. The length of the gib head, measured parallel with the shaft, shall be equal to the width of the key. The foregoing dimensions are approximate; the shape of the key and the depth of the keyway shall be such that the allowed unit stresses in shear and bearing will not be exceeded.

The length of the tapered part of the key shall be not less than that of the hub plus one-fourth of the diameter of the shaft.

If two keys are provided, they shall be placed 120 degrees apart.

Details of Design.

If practicable, the keyway in the shaft shall be made long enough to allow the key to be inserted without moving the hub along the shaft and long enough to extend beyond the point of the key, after the key is firmly seated, a distance not less than three-eighths of the diameter of the shaft. The clear distance between hub and head of key shall be not less than one-fourth of the diameter of the shaft.

Capacity of Keys.

438. The foregoing requirements for keys and keyways are for machinery parts whose use is intended to develop the full torsional strength of the shaft. For minor parts, the keys and keyways shall be proportioned for that size of shaft whose torsional strength would be developed by such parts.

For trunnions and similar parts which are designed chiefly for bending and bearing, the keys and keyways shall be proportioned simply to hold the trunnion from rotating. The force tending to cause rotation shall be taken as one-fifth of the load on the trunnion, and as acting at the circumference of the trunnion.

Fastening Keys.

439. Keys shall be held by safety set screws or other effective means. In vertical shafts, bands clamped about the shaft, or other devices, shall be placed below the key.

If practicable, the keys and keyways shall be so made that the keys may be backed out.

Hubs.

440. If practicable, the length of the hub shall be not less than 1¼ times the width of the teeth and preferably not less than the diameter of the bore; the thickness not less than two-fifths of the diameter of the bore.

The fit of the hub on the shaft shall be obtained by observing the following variations from the nominal diameter in inches.

Nominal Diameter Inches	Diameter of Hole, Inches		Diameter of Shaft, Inches	
	Maximum	Minimum	Maximum	Minimum
1	1	0.998	0.999	0.998
2	2	1.998	1.999	1.998
3	3	2.998	2.999	2.998
4	4	3.997	3.998	3.997
5	5	4.997	4.998	4.997
6	6	5.997	5.998	5.997
7	7	6.996	6.997	6.996
8	8	7.996	7.997	7.996
9	9	8.996	8.997	8.996
10	10	9.996	9.997	9.996

Details of Design.

Counterweight sheaves of vertical lift bridges, and main pinions, shall have pressed fits with keys.

The keyway in the hub shall be on the center line of an arm.

Bolts and Nuts.

441. Bolt heads and nuts shall bear on seats at right angles to the bolts. On castings, except where recessed, the bearing shall be on finished bosses or spot faced seats. Bolt heads which are recessed in castings shall be square.

Nuts which are subject to vibration and frequent changes of load shall be secured by effective locks. If double nuts are used, both nuts shall be of standard thickness.

Set Screws.

442. Set screws shall not be used for transmitting torsion; they may be used for holding keys or light parts in place.

Tap Bolts and Stud Bolts.

443. Tap bolts and stud bolts shall not be used except by special permission of the Engineer.

Operating Ropes.

444. For operating ropes, there shall be at least two full turns of the rope on the drum when the span is in the fully open or fully closed position. If practicable, the number of turns shall be sufficient to develop the ultimate strength of the rope by friction, the coefficient of friction being taken as 0.20. The rope shall be so attached to the drum as to avoid sharp bends in the wires. There shall be a turnbuckle or other device for taking up slack in the rope.

Counterweight Ropes.

445. The deviation of counterweight ropes from the vertical shall be as small as practicable. The deviation from the plane through the center of the groove shall not exceed 1 in 40.

Rope connections shall be so made that any rope may be renewed without disturbing the other ropes.

Safety Guards.

446. Safety guards for the protection of persons shall be installed. All safety regulations shall be observed.

Built Sheaves.

447. In built sheaves, there shall be enough rivets connecting the flanges of the cast rim with the web to carry into the web all of the load coming on the rim. The rim shall be strengthened by transverse ribs, or shall be thick enough to carry the load.

Drain Holes.

448. At places where water is likely to collect, there shall be drain holes not less than one inch in diameter.

Details of Design—Wire Ropes.

Equalizing Levers.

449. The net section back of the pin hole in equalizing levers shall be equal to the net section which would be required in tension to carry the load on the pin.

(5) WIRE ROPES AND ATTACHMENTS

Manufacturer.

501. Wire rope shall be made by a manufacturer whose facilities and reputation are approved by the Engineer.

Laying.

502. Ropes shall be laid in accordance with the best practice, in an approved lubricant.

Splices.

503. Ropes shall not be spliced.

Wires—Size and Number.

504. The diameter of counterweight ropes shall be not less than one inch, nor more than two and one-half inches; of operating ropes not less than three-fourths of an inch.

The ropes shall be made of improved plow steel and shall consist of six strands of 19 wires each laid around a hemp center.

Sockets.

505. Sockets shall be forged without welds from solid steel. The dimensions of sockets shall be such that no part under tension will be stressed higher than 65,000 lb. per square inch when the rope is stressed to its specified ultimate strength. The sockets shall be attached to the rope by a method which is reliable and which will not permit the rope to slip in its attachment to the socket.

Wire—Physical Properties.

506. The wire from which counterweight ropes are made shall be tested in the presence of an inspector designated by the Engineer. It shall show the following physical properties:

(a) A tensile strength of not less than 225,000 lb. a square inch.

(b) A total elongation (measured on a piece 12 inches long) of not less than 2.4 per cent.

(c) The number of times a piece six inches long can be twisted around its longitudinal axis without rupture shall be not less than 1.4 divided by the diameter in inches.

(d) The number of times the wire can be bent 90 degrees alternately in opposite directions over a jaw the radius of which is equal to twice the diameter of the wire, without fracture, shall be not less than six. This test shall be made in a mechanical bender so constructed that the wire actually conforms to the radius of the jaws and is subjected to little tensile stress.

Wire Ropes and Attachments.

Ultimate Strength.

507. In order to test the strength of the rope and fastenings, a number of test pieces not more than twelve feet long, with sockets (selected at random from those which are to be used in filling the order) attached to each end, shall be stressed to destruction in a suitable testing machine. The number of test pieces shall be not more than ten per cent. of the total number of finished lengths of rope to be made, nor less than two from each original length. Under this test, the rope shall develop the ultimate strength given in the table below:

ULTIMATE STRENGTH OF 6x19 IMPROVED PLOW STEEL ROPE

Diameter of Rope in Inches	Area of Section $0.4D^2$	Ultimate Strength Pounds	
		Per Sq. Inch	Entire Rope
½	0.100	210,000	21,000
⅝	0.156	208,000	32,000
¾	0.225	206,000	46,000
⅞	0.306	204,000	63,000
1	0.400	202,000	81,000
1⅛	0.506	200,000	101,000
1¼	0.625	198,000	124,000
1⅜	0.756	196,000	148,000
1½	0.900	194,000	175,000
1⅝	1.056	192,000	202,000
1¾	1.225	190,000	233,000
1⅞	1.406	188,000	264,000
2	1.600	186,000	298,000
2¼	2.025	184,000	373,000
2½	2.500	182,000	455,000

Rejection.

508. If the physical qualities of the rope or of its individual wires fall below those specified, the entire length from which the test pieces were taken shall be replaced by the manufacturer with a new length, the physical qualities of which conform to those specified.

Testing Sockets.

509. If slipping in the sockets should occur during the test, the method of fastening the sockets shall be changed until slipping does not occur. The sockets shall be stronger than the rope to which they are attached. If a socket should break during the test, two others shall be selected and attached to another piece of rope and the test repeated. This process shall be continued until the Inspector is satisfied as to the reliability of the sockets. If the Inspector is satisfied, the lot shall be accepted. If, however, 10 per cent. or more of the sockets tested break at a load less than the specified minimum ultimate strength of the rope, the lot shall be rejected.

Wire Ropes and Attachments—Power Equipment.

Facilities for Testing.

510. The manufacturer shall provide proper facilities for making the tests, and shall make, at his own expense, the tests required. Tests shall be made in the presence of an Inspector representing the Engineer.

Length.

511. The length of each rope shall be measured while the rope is supported throughout its length in a straight line and under a tension of 2 per cent. of its ultimate strength. A variation from the required length of not more than one-quarter of an inch in 100 feet will be allowed.

Coils.

512. Ropes shall be shipped on reels of a diameter not less than thirty times that of the rope.

Equalizing Levers.

513. The equalizing levers, and their pins more than seven inches in diameter, shall be of forged steel. Pins seven inches or less in diameter shall be of either rolled steel or forged steel.

(6) POWER EQUIPMENT

(a) General Requirements

Kind of Power.

601. If the bridge is to be operated by mechanical power, the kind of power to be used will be stipulated by the Company. The motors shall be of ample capacity to move the bridge at the required speed. The type of the motor and the name of the manufacturer shall be given in the bid. The term motor, as used in these specifications, means the prime mover whether steam, internal combustion, or electric.

Man Power.

602. If the bridge is to be operated by hand, the number of men and the time required to operate it shall be calculated on the assumption that the force one man can exert continuously is 40 lb. at a speed of 160 ft. per minute, developing about one-fifth h.p. For calculating the strength of the machinery parts, the force of one man shall be assumed as 125 lb., and the force applied to the extreme end of a hand lever shall be assumed as 150 lb.

Machines.

603. Machines which are of the usual manufactured types, such as steam, gasoline, and electric motors, pumps, air compressors, etc., shall be tested for the specified requirements to the satisfaction of the Engineer, and shall be guaranteed by the Contractor to fulfill these requirements for one year.

Power Equipment.

Torque of Motors.

604. The motors shall be capable of exerting, through successive cycles of bridge operation extending through 30 minutes, the torques shown on the torque curves for the loads specified in Art. 308; and for 15 minutes, twice those torques. A cycle is defined as an opening and a closing of the bridge without a period of rest between closing and opening, and without a change of wind in amount or direction. Successive cycles shall be taken without periods of rest.

Electrical Control.

605. The electrical control shall be manual, remote, or automatic. The kind will be stipulated by the Company.

Brakes.

606. Electrically operated vertical lift bridges shall be provided with a solenoid brake for each main motor, and in addition a motor operated service brake with three steps of retarding torque. If stipulated, the service brake shall be operated by air, or by hand.

Electrically operated bascule bridges and swing bridges shall be provided with a solenoid brake for each main motor, and in addition with an emergency brake which shall be located as close to the operating rack as practicable.

Brakes for bridges operated by power other than electricity shall be operated by air, by hand, or by foot.

Whistle or Horn.

607. A whistle or an electric horn shall be installed complete.

The horn shall be audible at a distance of 1,500 feet under the conditions surrounding the site and with the wind blowing in any direction.

The bell of the whistle shall be not less than 3 inches in diameter and 9 inches long. If the whistle is operated by air, the compressor shall be power driven, the motor and compressor being gear connected on one frame. The working parts shall be enclosed and self-lubricating. The compressor shall have a piston displacement of from 25 to 30 cubic feet a minute when working against a tank pressure of 90 lb. a square inch. The compressor shall be provided with an automatic governor and switch in order that the compressor may start and stop automatically at any predetermined tank pressure.

The air receiving tank shall be 36 inches in diameter and 8 feet long, or of equal capacity. It shall be good for a working pressure of 125 lb. a square inch. It shall be provided with pressure gage, pop valve, and drain cock, and shall have standard flanges bushed for 1½-inch pipe. The Contractor shall furnish and install pipe, pipe fittings and valves; all to withstand a working pressure of 125 lb. a square inch.

Power Equipment.

(b) Steam

Steam Engines.

608. Steam engines shall be of the double-cylinder, reversing type, and shall develop the required power at a piston speed not exceeding 500 feet per minute with a steam pressure of 75 lb. per square inch at the throttle. The engine shall be connected to the operating machinery by an approved friction clutch, so arranged that the moving machinery and the locking machinery may be operated independently or stopped without stopping the engine.

Steam Separator.

609. There shall be a steam separator in the steam supply pipe close to the steam chest. This separator, under test with quality of steam as low as 66 per cent., shall show an average efficiency of 85 per cent. in five tests.

Boilers.

610. There shall be installed one or two boilers as stipulated. The boilers shall be upright tubular boilers with submerged tubes. They shall be designed for a steam pressure of 150 lb. per square inch, and shall be adapted to the kind of fuel specified by the Engineer. Boilers shall be in accordance with the Code of the American Society of Mechanical Engineers, adopted February, 1915, with additions and revisions, and shall conform to civil regulations. They shall be encased in asbestos covered with planished iron.

Boiler stacks and breechings shall be made of ingot iron not less than $\frac{3}{16}$-inch thick. They shall be of ample diameter and height to furnish the required draft under the conditions at the site. There shall be a damper in the stack.

Horse-power of Boilers.

611. The capacity or boiler horsepower of each boiler shall be such as to furnish at least twice the quantity of steam required by the engine when it is working at the specified steam consumption rate for the brake horsepower required. At least 15 square feet of heating surface and one-third square foot of grate surface shall be allowed for each boiler horsepower.

Pipes and Coverings.

612. Steam pipes and fittings shall be extra heavy and shall be covered with 85 per cent. magnesia sectional covering jacketed in canvas. Water pipes shall be protected from freezing, if necessary.

Engine Room Appliances.

613. In the engine room, there shall be a steel water tank of sufficient capacity, a duplex steam boiler feed pump, and an injector for each boiler, with necessary pipes and connections for feeding boilers separately or together. Steam water lifters with necessary strainers, flexible hose, and

Power Equipment.

piping to lift the water from the river into the tank shall be provided if the river water is fit for boiler use. A coal hoist and a steel coal bin of sufficient capacity shall be provided. There shall be in the engine room indicators to show the position of the moving span and of the lifting and locking apparatus.

(c) Internal Combustion

Gasoline Engines.

614. Gasoline and other internal combustion engines shall be of the automobile or the marine type and of the most substantial kind. The piston speed shall not exceed 1,600 feet a minute. The engine shall be equipped with a reversing gear with approved friction clutches, to be operated by a hand wheel or lever. The countershaft connecting the engine with the operating machinery shall be provided with disengaging couplings so arranged that the moving machinery and the end lifting or end locking machinery may be operated independently and in either direction without stopping the engine. Engines of 20 h.p. or more shall be equipped with a starting device actuated by an electric motor or by compressed air. A tank of sufficient capacity for cooling water, or a radiator and fan, shall be installed in the engine room. The fuel tank shall be located outside the engine room, below the level of the cylinder. The tank shall be large enough to hold fuel for 30 days of normal operation. It shall be protected from the sun.

There shall be in the engine room indicators to show the positions of the moving span and of the lifting and locking apparatus.

Ignition.

615. If the fuel is suitable (such as gasoline and kerosene) the ignition shall be of the jump-spark kind, for which the secondary coil is made up so that a low voltage primary current (not more than 24 volts) will be sufficient. For other fuel, the best device available shall be used.

Spare Parts.

616. Two extra ignitors and two extra crank pin brasses shall be furnished.

(d) Electric

Rules.

617. The electrical equipment shall conform to the Standardization Rules of the American Institute of Electrical Engineers as adopted June 28, 1916, with additions and revisions.

The National Electric Code and local ordinances shall apply to the electrical material, construction, and installation, except as provided otherwise herein.

Wires, Etc.

618. The quality of the wires, cables, and insulation (except slow burning insulation) shall conform to the Railroad Specifications for Electric Wires and Cables of the American Railway Engineering Association as adopted in 1921, with additions and revisions. Wires and cables shall be subject to inspection during manufacture.

Power Equipment.

Motors.

619. A.C. motors for 25 cycles and D.C. motors shall be of the mill type. A.C. motors for 60 cycles may be of the crane type. The motors shall be totally enclosed and made as nearly weatherproof as practicable. They shall be so mounted as to admit of easy access for inspection and repairs. The frame, if practicable, shall be split, to allow the top part to be removed for taking out the armature without disturbing the mounting of the motor. The motors shall be securely supported and anchored. There shall be a close fit of the anchor bolts in the holes. If installed on the moving span, the motors shall be capable of being operated satisfactorily in any position.

Tests.

620. Motors of 50 h.p. or more shall be tested at the factory by the manufacturer in the presence of the Company's Inspector. Certified copies of factory tests of all electrically operated devices shall be furnished by the Contractor.

Design of Electrical Parts.

621. Electrical parts, such as wires, switches, etc., shall be designed for the currents required for the motors when they exert the normal torques called for by the torque curves, on the supposition of continuous operation for one hour through successive cycles of bridge operation. For twice the normal torques and 15-minute operation, the temperature rise of the parts shall not exceed that for one-hour operation under normal torques. The excess torques shall be taken through successive cycles of bridge operation. The allowable drop at the motor terminals shall not exceed five per cent. of the supply voltage measured at the switch board.

Working Plans.

622. The Contractor shall make complete working plans for the electrical equipment. The tracings shall become the property of the Company after they have been corrected to show the work as constructed. These plans shall show:

a. Complete wiring diagram, giving size of the wires and the make and capacity of all apparatus.
b. Complete piping diagram, giving size and location of the conduits with the number and size of wires in each.
c. Size and location of the switchboard.
d. Location of the lamps.
e. Location of the controllers, limit switches, and foot switches.
f. Size and location of resistances.
g. The numbering of the circuits corresponding to numbered tags.
h. A curve of the current required by the motors at the various stages of operation.

Special apparatus shall be designated by the manufacturer's name and catalogue reference.

Power Equipment.

Number of Motors.

623. If the total power output at the motor pinion (under loads specified in (A) of Art. 308) to move the bridge at the required speed exceeds 25 h.p., there shall be two main operating motors, alike.

Motor Tests.

624. Any motor under test shall develop the required horsepower and torque at the armature shaft. Characteristic curves showing the results of the test shall be furnished by the Contractor.

Starting Torque.

625. The sum of the starting torques of the two motors (or the starting torque of the motor for a single motor installation) shall be equal to at least twice the greatest torque shown by the torque curves for the bridge operating machinery. The stalling torque of alternating current motors shall be equal to at least 1¼ times the starting torque.

Speed of Motors.

626. The r.p.m. of motors of 10 h.p. or more at the rated output shall not exceed 750; of the countershaft, 150. For other motors the r.p.m. shall not exceed 1,200; of the countershaft, 250.

D. C. Motors.

627. Direct current motors shall be of the series type with commutating poles. They shall be designed for the service characteristics specified. Each motor shall be capable of delivering its rated output continuously for 30 minutes without exceeding 55 degrees C. rise in temperature.

If the motors are used for dynamic braking, they shall perform that function without injurious sparking or temperature rise.

A. C. Motors.

628. Alternating current motors shall be of the induction type designed for the service characteristics specified. Those of more than 5 h.p. shall have slip rings. Each slip ring motor shall be capable of delivering its rated output continuously for 30 minutes without exceeding 55 degrees C. rise in temperature. For squirrel cage motors the time shall be 15 minutes. Squirrel cage motors shall have high resistance rotors.

Heat tests, potential tests, and temperature corrections shall be in accordance with the Standardization Rules of the American Institute of Electrical Engineers.

Weather Protection.

629. The field and armature coils of motors shall be rendered moistureproof by treatment with a special compound. Motors outside of the machinery house shall be housed in a weatherproof metal housing. This housing shall be arranged to allow the motor to be inspected and oiled, and shall be readily removable. The metal in the housing shall be galvanized and not thinner than No. 16 U. S. Standard gage.

Power Equipment.

Back-Geared Motors.

630. In back-geared motors, one cast steel cut gear (bored and key-seated for attachment to the countershaft) shall be furnished with the motor. The gear ratio shall be such that the speed of the countershaft will not be more than 250 revolutions per minute. The gear and pinion shall be covered by a sheet steel or malleable iron split gear case, supported by the motor frame. An opening with a hinged cover shall be provided in the gear case for inspection and oiling.

Spare Parts.

631. The Contractor shall furnish the following spare parts:

a. A set of fuses, not less than six of each kind.

b. A set of contacts and contact fingers for each device.

c. One brake coil for each size of brake.

d. One coil for each size of magnetic switch.

e. For each size of motor:
   One pinion, or one pinion and gear for back-geared motors.
   One set of brushes.
   One set of motor bearing linings.

   For D.C. Motors:
   One armature complete with shaft and commutator.
   One series field coil.
   One commutating field coil.

   For A.C. Motors:
   One rotor complete with shaft and slip rings.
   One complete set of stator coils.

Controllers.

632. There shall be in the operator's house one controller for the operation of each main motor, one for each rail lock motor, one for each bridge lock motor and one for each end lift motor. For manual control of motors in parallel, the controllers shall be interconnected so that all controllers will be operated simultaneously through any one controller handle manipulation. The controllers shall be so arranged that the operation of any motor may be cut out by pulling a switch without affecting the operation of any other motor.

The controllers shall be of the reversing drum or flat type. Direct current controllers shall have a magnetic blowout. The controllers shall be capable of varying and maintaining the speed of the motors throughout the entire range desired, without injurious sparking, and without shock due to sudden variation in speed. They shall be capable of doing their work under the greatest loads that may come upon the motors with a temperature rise not exceeding 30 degrees C.

633. The number of steps in controllers for main motors shall be such that the minimum or maximum motor torque will not differ by more than ten per cent. from the average torque required for uniform acceleration of the bridge against all resistances.

For automatic control, there shall be no fewer than four; for manual control, no fewer than five points of acceleration.

Power Equipment.

634. Where there are two main D.C. motors, the controller shall be of the series-parallel type if the current is furnished by a storage battery. For other D.C. motors the control shall be parallel throughout. The field of interpole motors may be varied.

Resistances.

635. For more than 25 amperes, rheostatic units shall be of the cast grid type. The rheostat shall be of such capacity that any part of it will carry continuously for five minutes the root-mean-square current for the heaviest cycle of motor operation with a temperature not exceeding 350 degrees C. The units or sections shall be so mounted on a steel frame as to be free from injurious vibration and to permit free circulation of air around them; and so that any unit or part of unit may be removed and replaced without disturbing the others. The units shall be insulated from their supports. For less than 25 amperes, other types of units may be used.

Remote Control.

636. When the rated capacity of each motor requires more than 200 amperes, the motors shall have remote control. The motor circuits shall be made by contactors mounted on unit slate panels. The contactors shall be operated by solenoids controlled by a master controller.

Automatic and Remote Control.

637. The following features apply to remote and to automatic control:

1. Direct Current.

(a) *Controller Equipment.* The controller panel shall be made of unit slate panels mounted on an angle iron frame.

Single or double-pole contactors of the shunt type for reversing the motors shall be installed. A single-pole shunt contactor shall be provided for opening the side of the line opposite to that opened by the reversing contactors.

A separate overload relay shall be provided to open each side of the line in case of overload or ground. The overload relays shall open both sides of the line. Upon tripping they shall reset by bringing the master controller to the off-point.

(b) *Master Controller.* The master controller shall be of the drum type, reversing with single handle and provided with necessary contacts and fingers for operating the contactors on the controller panel. The contacts and wearing parts shall be easily removable and replaceable. Controllers shall be provided with speed control for the motors. Controllers shall be of the automatic, reversing, magnetic contactor type, with an individual, series wound relay for each shunt wound acceleration contactor.

For parallel or series-parallel operation, the controllers shall have individual reversing switches and separate resistors for each motor with separate acceleration contactors controlled by one train of series wound acceleration relays, to prevent a direct path for current from one motor to the other.

Power Equipment.

(c) *Knife Switch.* One double-pole, single throw, mill type, fused, knife, service switch shall be mounted on a controller panel for each main operating motor. A double-pole, single throw, fused, knife switch for cutting off the control circuits shall be installed.

(d) *Series Switches.* Adjusting plugs, screws, and nuts shall be easily accessible, to allow the series switches to be adjusted for closing value while the controller is operating.

(e) *Interlocks.* The reversing shunt switches shall be electrically and mechanically interlocked to prevent the closing of the reversing switches until the forward switches shall have opened. The reversing switches and the series switches shall be electrically interlocked to prevent the closing of the reversing switches while the forward switches or any series switch is closed.

(f) *Contacts.* Contacts on shunt switches and series switches shall be removable without disturbing any other part of the switch.

2. Alternating Current.

(a) *Controller Equipment.* The controller panel shall be made of unit slate panels mounted on an angle iron frame.

Double or triple-pole contactors of the shunt type for reversing the motors shall be installed.

An inverse time element overload relay shall be provided in each of two lines of a three-phase circuit which will open all three lines of the circuit. Upon tripping, the overload relay shall reset by bringing the master controller to the off-point. If double-pole contactors are used to reverse the motors, another contactor shall be supplied to open the other line (not opened by the reversing switches) in case of overload or ground.

(b) *Master Controller.* The master controller shall be of the drum type, reversing with single handle, and provided with necessary contacts and fingers for operating the contactors on the controller panel. The contacts and wearing parts shall be easily removable and replaceable. Controllers shall be provided with speed control for the motors.

Controllers shall be of the automatic, reversing, magnetic contactor type with an individual, series wound relay for each shunt wound acceleration contactor.

For parallel operation, the controllers shall have separate acceleration contactors connected to separate resistors for each motor. Each phase shall have its own resistors, so designed as to give balanced current in all three phases. The acceleration contactors shall be so designed, or electrically or mechanically connected, that corresponding circuits in each motor control will be made simultaneously, and that in the event of one motor being cut out the control for the motor still in use will operate satisfactorily. The motors shall have individual reversing switches.

The entire controlling apparatus must operate satisfactorily without chattering, between 80 and 105 per cent. of normal line voltage at the switchboard and must be capable of operating the bridge through continuous and successive cycles of operation. No-voltage protection, which will open the motor circuits on failure of power, shall be furnished.

Power Equipment.

(c) *Knife Switch.* One triple-pole, single throw, mill type, fused, knife, service switch shall be provided for each main operating motor.

A single throw, fused, knife switch for cutting off the control circuits shall be installed. This switch shall have a pole for each wire energizing the control circuit.

(d) *Series Switches.* Adjusting plugs, screws, and nuts, including time limit adjustment, shall be easily accessible, to allow the series switches to be adjusted for closing value while the controller is in operation.

(e) *Interlocks.* The reversing shunt switches shall be electrically and mechanically interlocked to prevent the closing of the reversing switches until the forward switches shall have opened. The reversing switches and the series switches shall be electrically interlocked to prevent the closing of the reversing switches while the forward switches or any series switch is closed.

(f) *Contacts.* Contacts on shunt switches and series switches shall be removable without disturbing any other part of the switch.

Brakes.

638. The main motors and end lift motors shall be provided with post brakes which are held in the set position by a spring or a weight with such force as to overcome the full load torque of the motor. The brakes for other motors may be of either the post or disc type. The friction surfaces shall be of materials which are not affected by moisture. The brakes for main motors shall be arranged to be released by shunt coil solenoids; for other motors, by series coil solenoids. The solenoids shall have ample power, and heat dissipating capacity; and shall set automatically whenever the current fails or is cut off from the motors. Disc brakes shall be dry brakes. Solenoids shall be moisture-proof. Brakes on main operating motors shall be provided with a foot-switch release for coasting purpose. Means shall be provided for releasing the brakes mechanically.

Air Brakes.

639. If air brakes are used, they shall be controlled from the operator's house. The air compressor shall be electrically operated, and shall be able to compress 11 cu. ft. of free air a minute against a tank pressure of 90 lb. a square inch. The loss of pressure through the valves of the compressor shall be not more than 1½ lb. in ten minutes. The pressure at the tank shall be maintained automatically between 60 and 90 lb.

The air tank shall be cylindrical with a capacity of at least 10 cu. ft. It shall be built up of boiler plate with riveted joints. It shall show no leaks when tested at a pressure of 160 lb. a square inch.

The brake cylinder shall have a spring release capable of placing the brake in the released position automatically as soon as the air is exhausted. The cylinder shall be not less than 6 inches in diameter with a stroke of not more than 6 inches.

At a convenient place in the line carrying air to the brake cylinder, there shall be a union with a choke which will introduce a period of at least five seconds for establishing the tank pressure in the cylinder.

Power Equipment.

If the control of the air in the brake cylinder is remote and electrically operated, the arrangement of the application and release magnets shall be such that the brake will be applied in case of any power failure.

The pipe line between the compressor and the reservoir tank shall consist of not less than 50 feet of pipe. From the compressor, it shall run vertically upward to the highest point in the line. From this point, the line shall slope downward to the tank.

Emergency Brake.

640. The emergency brake shall be arranged to be released by a solenoid or a motor which will hold the brake in release as long as the current is applied. Cutting off the current from the solenoid or motor or any failure of the current shall result in the instantaneous application of the brake. This brake normally shall be set and so arranged that it must be released by the operator before starting the bridge. It shall be held in release during the entire operation unless an emergency condition arises requiring brake power in excess of that offered by the motor brakes, in which case it may be applied instantly by the operator. This portion of the equipment shall be so designed that it will not be injured if left in release indefinitely. Means shall be provided for releasing the emergency brake mechanically.

641. The emergency brake motor circuit or solenoid circuit shall be independent of the general interlocking system, and there shall be an electrical interlocking device which will prevent the use of the main motors and the emergency brake one against the other, except at the instant of closing. At closing, the brake shall be applied automatically before the power is cut off from the main motors, to prevent rebounding of the span.

The emergency brake switch shall be attached to the controller stand within easy reach of the operator. Labels shall be placed back of the switch handle to indicate the set and the released positions of the brake.

Brake Housing.

642. Electrically operated brakes shall be housed.

Automatic Stops.

643. The bridge lock motors and the rail lock motors shall be arranged to be stopped and their brakes to be set automatically at each end of the travel. An automatic cut-off shall be provided which will cut off the current from the main motors and set the brakes so that the span will be stopped when the end is six feet from either the closed or the fully open position. A spring opening switch shall be provided which, if held closed, will put the cut-off out of service and thus enable the bridge operator to close or to fully open the bridge.

Switchboard.

644. The switches, cut-outs, circuit breakers, fuses, and meters shall be in the operator's house and mounted on an oil finished slate panel

Power Equipment.

switchboard, not less than 1½ inches thick and free from metallic veins and flaws. The bottom of the board shall clear the floor by at least nine inches. There shall be a distance of at least three feet between the wall and any of the parts on the back of the switchboard. The appliances mounted on the switchboard shall be provided with plates designating their uses.

The switchboard, switches, and controlling devices shall be designed and installed with a view to the safety of the operator.

Meters—Ground Detector.

645. A voltmeter and an ammeter shall be provided and installed on the switchboard. The switchboard instruments shall be illuminated. A voltmeter switch shall be provided which will allow the voltage between any two mains and the voltage between any main and the ground to be measured.

Switches.

646. There shall be a main switch of the quick break type with a pole for each supply wire and a switch in each motor, light, signal, indicator, or other circuit.

Circuit Breakers and Fuses.

647. An automatic circuit breaker shall be placed in the supply line. There shall be an enclosed fuse in each line to a motor, in each line to an electric brake, and in each line of lighting, signal, indicator, or other circuit. Fuses for circuits of 60 amperes or more shall have knife blade contacts.

Emergency Switches.

648. Emergency switches which will free the various motors from the interlocking in emergency shall be mounted on the switchboard and shall be covered by individually sealed glass cases.

Switches.

649. Switches shall be designed to carry not more than 900 amperes per square inch of cross-section. Knife switches shall be of not less than 100 amperes capacity. The blades or clips of knife switches and similar parts shall be not less than $\frac{3}{32}$-inch thick. Snap switches shall not be installed in circuits carrying more than 6 amperes. They shall be of not less than 20 amperes capacity.

Preferably, laminated switches shall not be used, but if used they shall have auxiliary carbon contacts which operate later.

Contact Areas.

650. Line contact in a circuit shall be avoided wherever practicable. The current per square inch of contact area shall not exceed 50 amperes for loose contact, or 100 amperes for bolted or clamped contact.

Power Equipment.

Magnetic Switches.

651. If magnetic switches are used, inverse time element overload relays, electrically and hand reset, shall be used for overload protection. Magnetic switches shall be quick acting, with wiping contacts well shielded to prevent arcing between the switch and other metal parts near. For direct current, the switches shall have magnetic blowouts. The switches shall have a minimum number of parts. Series magnetic switches shall not be used to break a current on opening.

Shunt Coils.

652. If shunt coils are used, in particular with brakes and magnetic switches, the insulation shall be such as to withstand the induced voltage caused by cutting off the current without the aid of external resistance.

Circuit Breakers.

653. Circuit breakers and fuses shall be designed to open the circuit when the motor is taking ten per cent. more current than is required to develop twice the greatest torque shown by the torque curves for the bridge operating machinery.

Circuit breakers shall have no fewer than two poles with a common trip, overload attachments, and an under-voltage release. There shall be individual closing arms for each pole. There shall be an overload coil in each line for direct current circuits, and in each of two lines of a three-phase, three-wire circuit. The overload attachments shall open the two lines of a direct current circuit and all lines of an alternating current circuit. Tripping attachments shall be positive in action.

Circuit breakers of the under-voltage or the shunt-trip types shall not be used for limiting the travel of any mechanism.

A limit switch shall be used in conjunction with a magnetic switch or contactors to stop the motors at the end of the travel.

Protection of Contacts.

654. Electrical contacts shall be protected from the weather and from accumulations of dirt.

Metal Covers.

655. Metal coverings for drum switches and similar parts shall be of not less than No. 16 U. S. Standard gage, galvanized iron. For built-up boxes, the metal shall be of not less than No. 11 U. S. Standard gage. Junction boxes preferably shall be made of malleable cast iron not less than $\frac{3}{16}$ inch thick, which will allow the conduits to be threaded into the box. The boxes must be weatherproof throughout, in particular at conduit connections, and be free from rough edges and from rough surfaces.

Cast Iron in Electrical Parts.

656. Cast iron, unless malleable, shall not be used in switches and small electrical parts which are located on the bridge.

Wires.

657. Wires of No. 10 B.&S. gage and larger and all wires in flexible connections shall be stranded. Wire smaller than No. 12 B.&S. gage shall not be used.

Power Equipment.

Splices.

658. Splices shall be neatly and carefully made. They shall be made mechanically and electrically secure before soldering. They shall be wrapped with rubber tape and friction tape and painted with waterproof insulating varnish. Splices shall not be inside of a conduit.

Conduits.

659. Wires shall be placed in metal conduits. The total area of the wires (including insulation) in any conduit shall not exceed 42 per cent. of the area of the conduit.

To lessen the inductive effects, the phase wires in alternating current motor circuits shall be placed close together in one conduit. Not more than three alternating current motor circuits shall be in one conduit. A circuit in three-phase work means three wires.

Conduits shall be sherardized on the inside and the outside. Sherardized condulets, pull-out boxes, ells, and other fittings shall be used with conduits. Bends shall be used sparingly. The total angle of bending between junction boxes or condulets shall not exceed 120 degrees. If the conduit is bent, the radius of the bend to the center of the conduit shall be not less than twelve times the inside diameter of the conduit; this requirement does not apply to factory ells. Junction boxes may be used where other fittings are not suitable. Conduits and boxes shall have suitably located drain holes. The length of conduit between junction boxes or condulets shall not exceed 70 feet.

Conduits shall be so placed that dirt will not accumulate around them. There shall be at least ½-inch clearance between them. If on a horizontal surface, they shall clear the surface by at least three inches.

Flexible Connections.

660. Where stationary conduits join the conduits on the moving span, flexible connections shall be installed. The flexible connections shall be connected at both ends by combination couplings to junction boxes with slate terminal boards. If the flexible connections are 20 feet or less in length, the wires shall be in flexible metal conduits; if more than 20 feet in length, the flexible connections shall be made of built-up cables with provision for carrying the weight of the wires and for mechanical protection of the wires. The wires in flexible connection shall be extra flexible.

Wires to Be Tagged.

661. Wires shall be numbered and the number permanently marked on durable metal tags so that any wire may be traced from the switchboard to the motor or to the source of power.

Collector Rings.

662. On swing bridges there shall be collector rings with the cables brought up to them on or through the center pivot. The collector rings shall be protected by a removable metal casing.

Power Equipment.

Rolled Steel Conductors.

663. In vertical lift bridges, the current for the main operating motors shall be conveyed to and from the span through copper contact strips supported continuously by rolled steel sections weighing not less than 5½ lb. a foot. The copper strip shall have sufficient conductance to carry the full current. The contact strip shall be at least ¼ inch thick and at least 1½ inches wide. Against the contact strip a sliding shoe shall be pressed by a spring or by gravity.

Submarine Cables.

664. Submarine cables shall be lead covered and steel armored. They shall be placed at least five feet below the bed of the navigable channel. The current and voltage, the number of conductors in the cable, the size and number of strands in each conductor, the length of the cable, and other data special to the location shall be as specified by the Company for each bridge. The cable shall be long enough to provide ample slack.

Indicators.

665. The Contractor shall furnish and install, in the operator's house, electric light indicators which will show to the operator the various positions of the bridge, especially the fully open, fully closed, nearly open, and nearly closed positions of the bridge, and the closed and open positions of the end lifts, rail locks, and bridge locks.

Lighting.

666. A complete electric lighting system shall be installed for the operator's house, stairways, signals, machinery, and the end lifting and locking apparatus. The system shall be designed and proportioned for the electric lighting service available. Wires shall be in metal conduits.

In the operator's house, there shall be fixed pendants of suitable length, with key sockets and deep cone, fire enameled, steel shades. For exterior lighting, deep bowl, fire enameled, steel reflectors, and weatherproof sockets shall be provided. The Company will furnish at the site one complete set of lamps. The Contractor shall place them in the sockets and shall be responsible for them until the acceptance of the work by the Engineer.

Circuits.

667. Circuits are classified according to the following list:

1. Circuits to motors.
2. Circuits to lamps other than indicator lamps of interlocking circuits.
    a. Lamps for operator's house.
    b. Lamps for stairways, walks, etc.
    c. Lamps for machinery.
    d. Lamps for navigation.
3. Circuits for interlocking of operating machinery, including indicator lamps.

There shall be an independent circuit for each motor, for each group of lamps, and for the interlocking. The use of a common return wire will not be allowed. Each circuit shall be protected and controlled by its own fuses and switches located on the switchboard or at an equally convenient point.

(7) MATERIALS

(a) Cast Steel

Cast Steel.

701. Steel for castings shall conform to the General Specifications for Steel Railway Bridges of the American Railway Engineering Association, except as provided otherwise herein.

A test to destruction on three castings selected from a lot may be substituted for the tensile test, in the case of small or unimportant castings. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended. A lot shall consist of all castings from the same melt or blow annealed in the same furnace charge.

Large castings shall be hammered all over while suspended. If cracks, flaws, defects, or weaknesses appear, the casting shall be rejected.

(b) Forged Steel

Forged Steel.

702. Steel for forging shall be made by the open-hearth or the crucible process and shall conform to the following chemical requirements:

Phosphorus, maximum ....0.04 per cent.
Sulphur, maximum ....0.05 per cent.

An analysis shall be made by the Contractor from a test ingot taken during the pouring of each melt. Check analyses may be made by the purchaser from drillings taken from (a), a full-sized prolongation of a forging from each melt at a point midway between center and surface, or (b), turnings from a test specimen. Both analyses shall conform to the requirements specified.

Check analyses may be made by the Engineer from a broken tension or bend test specimen. The phosphorus and sulphur content thus determined shall not exceed that specified by more than 20 per cent.

703. Annealed forged steel shall conform to the requirements in the following table:

FOR FORGINGS WHOSE MAXIMUM OUTSIDE DIAMETER OR OVER-ALL THICKNESS IS NOT OVER 20 INCHES

Size, Outside Diameter or Over-all Thickness	Tensile Strength, min., lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., min., per cent.		Reduction of Area, min., per cent.	
			Inverse Ratio	Not under	Inverse Ratio	Not under
Not over 8 in..........	75,000	0.5 tens. str.	$\frac{1,800,000}{\text{tens. str.}}$	20	$\frac{2,800,000}{\text{tens. str.}}$	33
Over 8 to 12 in., incl..	75,000	0.5 tens. str.	$\frac{1,725,000}{\text{tens. str.}}$	19	$\frac{2,640,000}{\text{tens. str.}}$	31
Over 12 to 20 in., incl...	75,000	0.5 tens. str.	$\frac{1,650,000}{\text{tens. str.}}$	18	$\frac{2,400,000}{\text{tens. str.}}$	29

Materials.

The tension test shall be made on a standard turned test specimen, ½ inch in diameter and 2 inches in gage length.

704. A specimen 1 inch by ½ inch shall bend cold 180 degrees around a diameter of ½ inch without cracking on the outside of the bend. The bending may be effected by pressure or by blows.

705. Forgings shall be free from cracks, flaws, seams, and other injurious defects.

706. Forgings shall be annealed. Before annealing, they shall be allowed to become cold after forging. They shall then be reheated uniformly to the proper temperature and allowed to cool uniformly.

707. Physical tests of forging shall be made after final treatment. Each annealing charge and each melt shall be tested.

If the tests do not show the required physical properties, the forgings may be reannealed, but not more than three times. If the tension specimen shows a fracture more than 15 per cent. crystalline, a second test shall be made. If the second fracture is more than 15 per cent. crystalline, the forgings shall be reannealed.

708. Test specimens shall be cut cold from the forging or from a full-sized prolongation of it. For forgings with large ends or collars, the test specimen shall be taken from a prolongation of the same diameter or cross-section as that of the forging back of the large end or collar. The axis of the specimen shall be half-way between the center and the outside, or for hollow forgings, half-way between the inner and outer surfaces. The length of the specimen shall be in the direction of the working or drawing out of the metal. Marks identifying the melt and annealing charge shall be stamped on each forging and on each test specimen by the Inspector before the specimen is cut.

(c) Tool Steel

Tool Steel.

709. Tool steel shall be made by the open-hearth or the crucible process. It shall conform to the following chemical requirements:

Carbon, maximum	1.00 per cent.
Phosphorus, maximum	0.04 per cent.
Sulphur, maximum	0.04 per cent.
Manganese, maximum	0.50 per cent.

(d) Bronzes

Bronzes.

710. Phosphor bronze shall be a homogeneous alloy of crystalline structure. It shall be made from new metals, except that scrap of known composition produced by the foundry at which the bronze is cast may be used. It shall not contain sulphur. The phosphorus shall be introduced in the form of phosphor-tin or phosphor-copper. Castings shall be sound, clean, and free from blow-holes, porous places, cracks, and other defects.

711. The hardness of the finished castings shall be tested by the Brinell ball method and a record of the test furnished. The ball shall

Materials.

be of hardened steel 10 mm. in diameter. The load shall be 500 kg. and shall be applied for 30 seconds to a finished plane surface. No fewer than two hardness tests shall be made on each heat. A test shall be made on each trunnion bearing and on each disc.

712. The alloy shall be cast into ingots and allowed to cool, and the castings shall be poured from the remelted ingots. Care shall be exercised that the metal is not overheated and that the temperature at pouring and the conditions of cooling are such as will be most likely to secure dense castings.

713. There shall be four grades.

Grade A is to be used for contact with hardened steel discs under pressures exceeding 1,500 lb. per square inch, such as are used in turntables and center bearing swing bridges.

Grade B is to be used for contact with soft steel at low speeds under pressures not exceeding 1,500 lb. per square inch, such as trunnions and journals of bascule and lift bridges.

Grade C is to be used for ordinary machinery bearings.

Grade D is to be used for gears, worm wheels, nuts, and similar parts which are subjected to other than compressive stresses.

714. The chemical and physical properties shall conform to the requirements in the following table:

ALLOY OF	GRADE			
	A	B	C	D
	Copper and tin	Copper and tin	Copper, tin and lead	Copper, tin and zinc
Copper per cent	....	....	82 max.	89 max.
Tin per cent	20 max.	17 max.	11 max.	11 max.
Lead per cent	....	....	11 max.	....
Zinc per cent	....	....	....	2.25 max.
Phosphorus per cent	1.0 max.	1.0 max.	1.0 max. 0.7 min.	0.25 max.
Other elements per cent	0.5 max.	0.5 max.	0.5 max.	0.5 max.
Elastic limit in compression, pounds per square inch	24,000 min.	18,000 min.	....	....
Permanent set in inches under 100,000 pounds per square inch	.06 min. .10 max.	.10 min. .20 max.	....	....
Permanent set in inches under 50,000 pounds per square inch	To be recorded	To be recorded	To be recorded	To be recorded
Yield point in tension, pounds per square inch	....	....	....	To be recorded
Ultimate strength in tension, pounds per square inch	....	....	....	33,000 min.
Elongation in 2 in. per cent	....	....	....	14 min.

Materials—Workmanship.

Cracks or other evidence of excessive brittleness in compression test specimens may be cause for rejection.

The chemical analysis of each heat shall be furnished.

715. Test specimens shall be made from coupons which are a part of the casting and which have been fed and cooled under the same conditions as the casting.

Compression test specimens shall be cylinders one inch high and of one square inch area. The elastic limit in compression shall be the load which gives a permanent set of 0.001 inch.

Tension test specimens shall be turned from a coupon not less than one inch in diameter to the form shown in Fig. 6 of the American Railway Engineering Association General Specifications for Steel Railway Bridges. The diameter of the turned specimen shall be ½ inch.

716. One or more compression tests shall be made from each melt for grades A, B, and C; and one compression and one tension test for grade D. For castings weighing over 100 lb. finished, the prescribed tests shall be made for each casting.

(e) Babbitt Metal

Babbitt Metal.

717. Babbitt metal shall be approximately of the following composition:

Copper	3.6 per cent.
Tin	89.3 per cent.
Antimony	7.1 per cent.

(8) WORKMANSHIP

Planing Girders.

801. In built track girders and segmental girders of rolling bascule bridges, and in the lower flanges of the drums of rim-bearing swing bridges, the edges of the webs, side plates, and angles shall be so planed that full bearing on the track plate will be secured.

Rack and Track.

802. In swing bridges, track segments shall be planed on the top and bottom and at the ends. Surfaces on which conical rollers bear shall be planed to the true bevel. The center line shall be scribed on the surface.

The toothed segments forming the rack shall be fitted accurately. Particular care shall be taken to have the pitch of the teeth at the joints accurate. The periphery of rack teeth shall be planed. The pitch line shall be scribed on the teeth.

In swing bridges, the rack segments shall be fitted to those of the track so that the center line of the track will be concentric with the pitch line of the rack.

The backs of racks which bear on metal surfaces and the surfaces in contact with them shall be planed.

Workmanship.

Tread Plates.

803. In rolling bridges, the top and bottom surfaces of the tread plates and the surfaces in contact with them shall be planed.

Rollers.

804. The periphery and faces at the rim of rollers and balance wheels shall be turned, the corners shall be rounded, and the center line of the rollers and balance wheels shall be scribed on the periphery. The hubs shall be bored accurately and faced on both ends.

Pivots.

805. Pivot stands and center castings of swing bridges shall be finished and fitted accurately. The base shall be faced truly at right angles to the axis and shall be turned on the circumference concentric with the axis.

Discs.

806. Steel discs shall be of tool steel. They shall be fitted accurately, finished to gage, and oil tempered. After hardening, they shall be ground accurately to the final finish. The sliding surfaces of steel and phosphor-bronze discs shall be polished. Disc centers shall be assembled, fitted accurately and match-marked.

Assembling Centers.

807. The complete center of a swing bridge, including rim girders, rack, track segments and rollers shall be assembled in the shop, aligned, fitted, drilled and the parts match-marked.

Fillets.

808. Shafts and trunnions shall be made with fillets where abrupt changes in section occur.

Journals.

809. Journals, trunnions, linings and other rubbing surfaces shall be polished after being machined. Journals of shafts which are not cold rolled shall be turned with a filleted collar on each end.

In journals and trunnions more than eight inches in diameter there shall be a hole bored lengthwise through the center. The diameter of the hole shall be about one-fifth of the diameter of the journal or trunnion.

Couplings.

810. The faces of flange and split muff couplings shall be planed to fit.

Hubs.

811. The hubs of wheels, pulleys, couplings, etc., shall be bored to a close fit on the shaft. If the hub performs the function of a collar, the end next to the bearing shall be faced. Hubs shall be bored accurately at the true center of the wheel.

Workmanship.

Linings.

812. Bearings shall be bored for the journal and finished smooth after the lining has been put in. The bearing shall be bored 1/50 inch larger than the diameter of the journal. Bearings for rack pinion shafts shall be bolted to the bracket supporting them and bored while so fastened to insure perfect alinement. The edges of oil grooves and the edges of linings shall be rounded.

Bronze linings shall be turned on the outside to fit the bored hole in the bearing.

Babbitt metal shall be poured in the bearings in such a way that the thickness of the lining after boring will be uniform.

Bearings.

813. The rubbing and bearing surfaces and the joints between cap and base of bearings shall be finished. The holes in cap and base shall be drilled. The holes in bearings for bolts fastening them to their supports shall be drilled $\frac{1}{32}$ inch larger than the bolts. The holes in the supports shall be reamed to fit after the bearings have been adjusted.

Gear Teeth.

814. The teeth of gears transmitting power for the operation of the bridge, bevel gears, and wheels in the gearing of any motor, shall be machine cut. The periphery and ends of teeth of gears shall be turned. The pitch circle shall be scribed on the teeth.

Bevel Gears.

815. The teeth of bevel gears shall be cut by a planer having a rectilinear motion in lines through the apex of the cone. Rotating milling cutters shall not be used for making bevel gears.

Machine Molding.

816. Uncut teeth shall be machine molded.

Worms and Worm Wheels.

817. Threads on worms shall be machine cut and the teeth of worm wheels shall fit the worm accurately with surface or line contact.

Keys and Keyways.

818. Keys shall be planed and keyways machine cut. The finish of the keys and keyways shall be such as to give the key a driving fit on the sides. Tapered keys shall bear on the top, bottom and sides; parallel faced keys on the sides only.

Castings.

819. Castings shall be cleaned and all fins and other irregularities removed so that they will have clean, smooth surfaces, suitable for this class of work. Castings which are to be attached to structural steel or other castings shall have their contact surfaces finished. Unfinished edges of bases, ribs and similar parts, shall be neatly cast with rounded corners. Inside angles shall have proper fillets. Bosses shall be finished to the correct plane.

Workmanship—Erection.

Bolt Holes and Turned Bolts.

820. Holes for unfinished bolts shall be drilled or reamed not more than $\frac{1}{16}$ inch larger in diameter than the bolt. The diameter of the shank of turned bolts shall be at least $\frac{1}{16}$ inch larger than the diameter of the threaded portion. The bolt shall be 1/64 inch smaller in diameter than the bolt hole.

Assembling Machinery.

821. If practicable, machinery parts shall be assembled on the supporting members in the shop. They shall be aligned and fitted, and holes in the supports shall be drilled with the members in correct relative position. The members shall be match-marked both to the supports and to each other, and re-erected in the same relative positions. If assembling is not practicable, the holes in the supports shall be left blank and drilled in the field after the machinery parts are assembled and aligned.

Sheaves.

822. The grooves in sheaves shall be turned. The shape of the grooves shall conform as closely as feasible to the rope section so that while the ropes shall run freely in the grooves, the sides of the grooves shall prevent the wire ropes from flattening under static loads, as when supporting counterweights. Built sheaves shall be assembled and permanently riveted before the grooves are turned.

Grooves in Trunnions.

823. The grooves in the surfaces of trunnions and similar large bearings shall be machine cut. Small inequalities may be removed by chipping and filing. The grooves shall be smooth, especially the rounded corners.

Holes for Sheaves for Vertical Lift Bridges.

824. In vertical lift bridges, the holes in the girders and columns for the bolts connecting the main sheave bearings to their supporting girders, shall be drilled from the solid through cast iron or steel templates on which the bearings were set and accurately aligned when the holes in the bearings were bored. The bolt holes and the bolts shall be turned to the same diameter and the bolts driven to place without injury to them, the bearings, the girders, or the columns.

Air Buffers.

825. The workmanship on air buffers shall be so accurate that the weight of the cylinder and its attachments will be sustained by the confined air for six minutes, with a piston travel not more than that which occurs during the closure of the bridge. The valves must be closed and the buffers balanced so that the whole weight is carried by the piston rod.

(9) ERECTION

901. The General Specifications for the Erection of Steel Railway Bridges of the American Railway Engineering Association shall apply to the erection of movable bridges, with additions specified herein.

Erection.

Protection of Parts.

902. Parts which are protected from the weather in the finished structure shall be protected in the field during erection by housing or equivalent means. This applies in particular to electrical parts.

903. Rubbing surfaces of trunnions and machinery bearings shall be protected by metal thimbles packed with oil-soaked waste.

904. Wire ropes shall be housed and stored at least 18 inches above the ground. The ropes shall be kept free from dirt, cinders, and sand. During erection, the ropes shall not be pulled through dirt, or bent into sharp angles or kinks.

Lubrication.

905. The counterweight ropes and the operating ropes shall be given two coats of dressing, with an interval of one month between the coats. The dressing shall not be applied in an atmospheric temperature below 40 degrees F. The Contractor, during erection, in particular just before the final test, shall lubricate the sliding parts and fill all grease cups.

Channel Lights.

906. During erection and in taking down the old span, the Contractor shall place and maintain navigation lights and signals, in accordance with the government requirements, for the protection of the falsework, as well as navigation.

Erection of Machinery.

907. The machinery shall be erected by men skilled in the work. Special care shall be given to the alinement of trunnion bearings.

Testing of Machinery.

908.. Before the main operating machinery is connected for transmitting power, it shall be given an idle run of 8 hours.

909. The end lifting devices shall be adjusted to produce a lift equal to the deflection caused by the negative end reaction of the live load and impact plus 25 per cent. of their sum.

910. The Contractor shall adjust the counterweight so that the span will be properly balanced.

Bridge Operator.

911. For a power operated bridge, the Contractor shall provide at his own expense, a competent man to supervise the operation of the bridge for a period of 30 days after acceptance. The man shall instruct the employees of the Company in the operation of the bridge.

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REPORT OF SPECIAL COMMITTEE ON STANDARDIZATION

E. A. Frink, *Chairman;*
J. R. W. Ambrose, *Vice-Chairman;*
W. C. Barrett,
Edwin B. Katte,
F. L. C. Bond,
A. Montzheimer,
W. A. Clark,
F. E. Morrow,
A. F. Dorley,
G. J. Ray,
W. T. Dorrance,
L. S. Rose,
W. J. Eck,
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J. M. R. Fairbairn,
F. J. Stimson,
W. D. Faucette,
H. M. Stout,
A. S. Going,
C. M. Taylor,
W. H. Hoyt,
W. P. Wiltsee,
Maro Johnson,
J. J. Yates,
C. E. Johnston,

Committee.

To the American Railway Engineering Association:

No subjects were assigned this Committee for study and report, but the following instructions were approved by the Committee on Outline of Work of the Board of Direction:

> Select articles, the standardization of which will benefit the consumers and the producers. Request the Committee on Outline of Work to have plans and specifications, if required, prepared by the appropriate standing committee and calling for as few sizes and types as will meet the needs of the consumers. Handle until a satisfactory design is obtained and promote its adoption by the roads and producers.

Progress Report

In its last report, pages 243-246, Volume 22, this Committee submitted a list of over forty articles to be considered for standardization. These have been referred by the Board of Direction to the appropriate committee for preparation of plans and specifications.

II—Ballast

The Committee on Ballast has prepared, and the American Railway Engineering Association has approved as recommended practice, specifications on page 100, and designs covering tamping bars, page 102; tamping picks, page 103; and ballast forks, page 104, of the Proceedings for 1921. These specifications and designs are being handled by this Committee with the purpose of securing their adoption by the roads and producers.

III—Ties

The American Railway Engineering Association was represented by the Tie Committee in a conference called by the American Engineering Standards Committee on the unification of Specifications for Cross-Ties and Switch Ties. At this meeting the American Railway Engineering Association was nominated as a sponsor for the project. The sponsorship has been accepted and Committee III is continuing to represent the Association and expects to present the specifications approved by our Association as a basis for unified specifications.

IV—Rail

During the year, the Rail Committee has endeavored to harmonize differences with the rail manufacturers on the standard specification for Open-Hearth Steel Rail, but so far without success. However, it is expected to have another meeting in January and at that time some progress may be made, which will be reported to the next Convention.

V—Track

During the past year, the Committee on Track has prepared plans for a number of track tools, railroad crossings, etc., which will be presented this year to the Association for adoption as recommended practice, and tentatively for standardization.

The Committee is glad to report that the manufacture of frogs and switches, previously adopted by the Association, is rapidly increasing and that the use of the Association's accepted designs for cut and screw spikes is being promoted as much as possible. Members of the Committee have been active toward securing adoption of these items on their railroads as standards, but have not made any extensive campaign toward standardization. It is the intention to start a campaign in the near future in behalf of the standardization of committee plans and specifications.

VIII—Masonry

The Committee on Masonry recommends that the Specifications and Tests for Portland Cement, adopted as recommended practice by the American Railway Engineering Association at the Convention in 1917, be accepted for standardization, except that paragraph 36 be omitted, which paragraph reads as follows:

> "Paragraph 36: A permissible variation of 1 will be allowed, and all results in excess of this specified limit but within this permissible variation shall be reported as 22 per cent."

The reason for this change is that this allowable variation has been omitted in general by those using the specifications.

IX—Signs, Fences and Crossings

The Committee on Signs, Fences and Crossings reports progress on the standardization work assigned it for this year.

X—Signals and Interlocking

The Committee recommends that the following drawings showing oil burning railway lamps and detail parts, RSA, 1100-1101, and ARA Signal Section Drawings 1430, 1440-1441-1442-1443-1445-14459-1460-1461-1470-1480-1496-1497-1498-1499, be submitted to the American Engineering Standards Committee for standardization.

XIII—Water Service

In July, a letter was received from Mr. C. R. Knowles, member of the Water Service Committee, advising that that Committee recommends the standardizing of the American Water Works Association's standards for cast iron pipe, hydrants, and valves. This was submitted to your Committee by letter-ballot and on September 23 the Board of Direction was advised that your Committee approves and recommends that these articles be adopted as standard.

XVII—Wood Preservation

The Committee on Wood Preservation has developed a situation whereby it would appear the present American Railway Engineering Association specifications for creosote oils tend to exclude what seem to be genuine coal tar creosote oils, and it is expected that there will have to be a change in our creosote oil specification before the next annual meeting.

A survey of the situation covering the creosote oil used by forty-two different railroads in the United States indicates that only a very small amount of oil now used comes up to our present specifications.

XVIII—Electricity

From the subjects submitted, the Committee on Electricity selected Friction and Rubber Tape, and will present to the Convention for approval a specification for Commercial Adhesive Tape for electrical purposes, and a specification for Rubber Insulating Tape. If approved by the Convention, these specifications will be presented to the American Engineering Standards Committee for standardization. Next year, the Committee will report on Insulators, or knife and snap switches.

CONCLUSIONS

The Committee recommends that the following subjects be submitted to the American Engineering Standards Committee by a representative of the American Railway Association before that Committee as a basis for standardization:

1. American Water Works Association standards for cast iron pipe, hydrants and valves, as approved by the Water Service Committee, and recommended by this Committee.
2. Tamping bars, tamping picks and ballast forks, pages 102-103-104, Volume 22, of the A.R.E.A. Proceedings, as reported by the Committee on Ballast and adopted at the last Convention.
3. Specifications as prepared by the Tie Committee of the A.R.E.A. and presented to the American Engineering Standards Committee by the Board of Direction.
4. Railway Lamps, as developed by the Committee on Signals and Interlocking, to be presented by that Committee at the next Convention.
5. Commercial Adhesive Tape and Rubber Insulating Tape, as specified by the Committee on Electricity, to be reported to the Convention this year.

Recommendations for Future Work

The need of standardization was never so great as at the present time. There is a useless diversity of types, and a considerable share of this waste is borne directly by the railroads. Indirectly, the roads, of course, bear their share of the burden. The outlook for standardization beneficial to the roads is improving, other associations are making good progress along similar lines, and your Committee feels that every effort should be made to follow up in detail the various possibilities that the subject offers. It believes the reward of success will be great and will result in economies which, especially at present, are greatly needed.

Respectfully submitted,

THE COMMITTEE ON STANDARDIZATION,

E. A. FRINK, *Chairman.*

REPORT OF COMMITTEE X—SIGNALS AND INTERLOCKING

W. J. Eck, *Chairman;*	W. M. Vandersluis, *Vice-Chairman;*
Azel Ames,	H. K. Lowry,
H. S. Balliet,	J. C. Mock,
A. M. Burt,	F. P. Patenall,
C. E. Denney,	J. A. Peabody,
F. L. Dodgson,	A. H. Rudd,
W. H. Elliott,	A. G. Shaver,
G. E. Ellis,	T. S. Stevens,
J. G. M. Leisenring,	E. E. Worthing,

Committee.

To the American Railway Engineering Association:

The subjects assigned to the Committee on Signals and Interlocking for study and report are shown on pages 13 and 14 of Bulletin No. 236, June, 1921.

(1) Revision of the Manual

Sub-Committee assigned to this work has furnished the Secretary information regarding the eliminations and additions required to bring the Manual up to date. The list of findings, conclusions, specifications and standard drawings has been reindexed for the purpose of easier identification.

(2) Report on Colors for Signals

Report on this subject will be found in the Proceedings of the American Railway Association, Signal Section, pages A-399 to A-409, July, 1920.

(5) Report on Light Signals

Requisites for light signals will be found in the Proceedings of the American Railway Association, Signal Section, pages 273 and 508, June, 1921.

(7) Requisites for Signal Locations

Report on this subject will be found in the Proceedings of the American Railway Association, Signal Section, on pages 510 to 531, June, 1921.

(8) Report on Automatic Train Control

This subject is now being handled by the Joint Committee on Automatic Train Control, members of which were appointed by the American Railway Association and the Interstate Commerce Commission.

(9) Aspect Indicating Train Must Take Siding at Non-Interlocked Switch

Report on this subject will be found in the Proceedings of the American Railway Association, Signal Section, pages 299 and 537, June, 1921.

(11) Effect of Electric Locomotive Headlights on Signals

But little difficulty has actually been experienced due to the effect of locomotive headlights and this has been largely eliminated with the abandonment of the arc light and the use of incandescent lamps in the headlights, with the consequent reduction in candlepower as well as the difference in characteristics of the two lights. The difficulties remaining are of three types:

(1) The preventing of a locomotive engineer on one train reading the signals which govern him on account of the headlight on a train in the opposing direction blinding him.

(2) Account of headlight on a train in the opposite direction showing through the colored glass on a dwarf signal other than the one in front of the lamp and so giving a wrong indication.

(3) Account of light from locomotive headlight on a train being reflected back from a signal and so giving a wrong indication.

The first of these difficulties has been obviated where they occur, which was mostly on multiple track territory, by having the enginemen dim the headlights when approaching trains running in the opposite direction.

The second difficulty has been obviated by arranging a shield on dwarf signals behind the colored glass of spectacles which are not in front of the lamp.

The third difficulty has been obviated by either:

(a) Adjustment of signal.
(b) Use of convex roundels.

The use of such roundels will obviate the trouble should signal not be in proper adjustment.

Recommendation.

The Committee recommends:

(1) That shields be installed on dwarf signals behind the colored roundels not in front of the lamp.
(2) That convex roundels be used on all new work and renewals.

(15) Outline of Work for Ensuing Year

1. Study the Manual and submit proposed revisions thereof.

2. Study the Manual and the work of the Committee and recommend matter that should be submitted as a basis for standardization.

3. Confer with other Committees on subjects affecting Signal Systems, viz:

Committee on Ballast on Standard Ballast Section.
Committee on Ties on Methods of Preservative Treatment.
Committee on Track on Switches and Track Details.
Committee on Masonry on Concrete.
Committee on Signs on Signs for Highway Grade Crossings.
Committee on Rules and Organization on Rules for Conduct of Signal Work and Guidance of Signal Employees.
Committee on Yards and Terminals on Signaling and Switching for Classification Yards.

Committee on Iron and Steel Structures on Rules for Operation and Lighting of Drawbridges.
Committee on Electricity on Interference with Signal Lines caused by Propulsion Currents; Overhead Wire Crossings and Specifications for Materials used in Signal Work.
Committee on Economics of Railway Operation on Methods of Increasing Track Capacity.

4. Recommend a carefully considered outline of work for the ensuing year.

Progress Report

Committee reports progress on the assignments not reported upon this year.

CONCLUSIONS

Committee recommends that the reports on assignments as given above be accepted as information.

Recommendations for Future Work

The Committee recommends that Report of Outline of Work (15) shown above be assigned the Committee for 1922.

Respectfully submitted,

The Committee on Signals and Interlocking,

W. J. Eck, *Chairman.*

REPORT OF COMMITTEE III—ON TIES

W. A. Clark, *Chairman;*
W. J. Burton, *Vice-Chairman;*
W. C. Baisinger,
M. S. Blaiklock,
F. Boardman,
S. B. Clement,
E. L. Crugar,
John Foley,
O. H. Frick,
G. F. Hand,
F. R. Layng,
R. M. Leeds,
A. F. Maischaider,
A. J. Neafie,
G. P. Palmer,
L. J. Riegler,
E. W. Boots,
H. A. Cassil,
F. W. Cherrington,
J. F. Deimling,
H. C. Hayes,
Lowry Smith,
H. A. Anderson,
Committee.

To the American Railway Engineering Association:

The Committee on Ties represented the American Railway Engineering Association in a Conference on the Unification of Tie Specifications, called by the American Engineering Standards Committee, at which the American Railway Engineering Association was nominated as a sponsor for this project. This sponsorship has been accepted and it is recommended that this Committee continue to represent the Association.

The Committee reports on the various subjects assigned as follows:

(1) Revision of Manual

No changes are recommended this year.

(2) The Economics of the Use of the Various Classes of Cross-Ties and Various Kinds of Preservative Treatment

In Appendix A the Committee submits the results of its study with conclusions and recommendations.

(3) Report on Substitute Ties

The Committee submits its report in Appendix B.

(4) The Care of Ties After Distribution

The Committee reports progress on this assignment; the data collected is being analyzed and the Committee expects to submit a final report next year.

(5) Classification of Ties for Various Kinds of Service

The above subject was combined with Subject 2 and is covered in Appendix A.

(6) The Effect of Design of Tie Plates and Track Spikes on the Durability of Cross-Ties and Results of Improperly Protecting Ties From Mechanical Wear

The Committee submits a final report in Appendix C.

(7) Outline of Work for the Ensuing Year

The recommendations of the Committee follow the conclusions of this report:

CONCLUSIONS

Your Committee recommends the following action on its report:

1. That the report on Subjects 2 and 5 be received as information and the recommendations pertaining to standard test ties be approved.
2. That the report on Substitute Ties be received as information.
3. That the report on Care of Ties after Distribution be continued.
4. That the report on Subject 6 be received as information and the subject discontinued.

Recommendations for Next Year's Work

1. Study the Manual and submit proposed revisions thereof.
2. Continue the study and report on substitute ties (progress report); also consider preparation of designs for substitute ties.
3. Continue the study and make final report, if practicable, on care of ties after distribution.
4. Prepare definite recommendations for installing and keeping records of test sections of track. (Final Report.) In 1920 the Committee made a report on this subject which was received as information. This report should be revised, if necessary, after obtaining criticisms from those having experience with test sections, and definite recommendations submitted for insertion in the Manual.
5. Report on service in this country of ties of foreign woods. (Progress Report.) Several railroads have imported ties for experimental use, and for the information of the Association, it is desirable to obtain as full reports as possible of these ties under different conditions of climate and service.

Respectfully submitted,

The Committee on Ties,

W. A. Clark, *Chairman.*

Appendix A

(2) ECONOMICS OF THE USE OF VARIOUS CLASSES OF CROSS-TIES AND VARIOUS KINDS OF PRESERVATIVE TREATMENT

(5) CLASSIFICATION OF TIES FOR VARIOUS KINDS OF SERVICE

W. J. Burton, *Chairman;* E. L. Crugar, H. C. Hayes, R. M. Leeds, A. F. Maischaider, G. P. Palmer, *Sub-Committee.*

Your Committee is of the opinion that these two subjects are so nearly alike that they can be considered the same, and this report, therefore, is intended to cover both.

Data.

Satisfactory report on these subjects would require tie life data which is non-existent, and not only is this true, but the Committee, after a careful consideration of the requirements, is of the opinion that the data from tests now under way will hardly be satisfactory for use in solving these problems. As the need for proper data will increase rather than decrease, with the diminishing timber supply, the Committee desires to point out wherein tie-life data is unsatisfactory and wherein tests may be made to produce more usable results.

It is recognized that the ultimate yardstick is the total cost per maintained mile per year under given traffic and climatic conditions, and that the tie which lasts longest will not necessarily show the lowest annual cost. However, the essential information necessary is—how long a certain kind of tie will last under *certain* conditions. The report of tests of ties so far made and under way are often more or less uncertain regarding the kind (size, timber, sapwood, etc.) of tie and usually very uncertain about the conditions of use. The life of a tie depends fully as much on where and how it is used as on what it was to start with.

The Committee realizes the difficulty of comparing installations under different conditions and is of the opinion that much of the trouble is due to an effort to obtain absolute rather than relative values for tie life.

Standard Test Tie.

If, in every test installation, there could be included a standard tie, to serve as a unit of comparison, the result, as measured by the standard tie, could be applied anywhere, where knowledge of the performance of the standard tie is available.

The Committee, therefore, recommends that in order to provide suitable data in the future the following practice with regard to test installations be followed:

(a) Install at the same point, in the same track, under the same traffic and under the same conditions of rail, ballast, drainage, sunlight, etc., an equal number, up to not less than 100, "Standard Test" ties.

(b) Continue the test record until all standard test ties have been removed as well as all other ties of the test.

(c) Standard test tie to be A. R. E. A. 1921 specification, grade 3 (6"x8"), class U, white oak, eight feet long, untreated.

(d) Record should include information called for on Form No. 1, Report of Experimental Test Tie Sections, as recommended by the Tie Committee, see page 339 of volume 22, A. R. E. A. Proceedings. This form calls for information as follows:

Location,
Kind of ballast,
Tangent or curve percentage,
Tie plates,
Weight of rail,
Rail fastenings,
Rail changed when,
Weight of rail originally in track,
Size of ties,
Kind of timber,
Where treated,
When treated,
How treated,
When put in track,
Number originally put in track,
Number still in track last inspection,
When last inspected,
Traffic,
Remarks.

In using this form the following data should be given:

1. Gross tons per year passing over the test, freight plus passenger.
2. Average annual rainfall.
3. Mean temperature of locality for January, and July, and highest and lowest extremes.
4. Ballast—kind and depth.

The tie selected as standard test can be secured, at least in the small numbers needed for test installations, without an undue amount of transportation to most of the country. The grade 3 is selected instead of grade 5 because it has shorter life.

Results With Available Data.

Comparable data as to life of treated ties is so limited that this report is made to cover untreated ties only. The method outlined, however, can be applied to such data as may be available. Owing to the need of proper data relative to treated ties, suitable for use in making comparisons of results, it is urged that comparative tests, using standard test ties, be undertaken by all roads using treated timber.

Table I has been prepared from the returns to the Committee's questionnaire of last year and from certain other data. The results are tabulated as percentages of the average life of untreated white oak, i. e., white oak taken at 100. Because of the limited amount of actual test data, the questionnaire specifically requested opinion data where actual was not available, and this tabulation, therefore, to a considerable extent reflects ideas rather than tested facts. However, owing to the lack of definiteness concerning many of the more important variables, as outlined above, this tabulation probably is as accurate as is possible to secure at this time.

It is to be noted that Table I concerns untreated ties only. It is also limited to returns which indicated that the failures were more than half caused by decay, and it is, therefore, an effort to compare the decay resisting qualities of untreated timber.

Mechanical Strength.

Cross-ties, as regards "design," must be considered from a somewhat different angle than most parts of a railroad. A tie could, theoretically at least, be designed of such size and strength as to carry the stresses imposed at any given location under given conditions. If the tie were to substantially retain its strength throughout its life, it would be comparable, as regards designing, with rails, bridges, etc. It does, however, lose its strength throughout its life, though we have no data as to whether this loss is proportional to the time (straight line) or otherwise, and it is economy, therefore, to use ties having an initial strength considerably greater than the stresses require, or in other words the new tie has reserve strength. It is believed that the amount of this reserve strength largely determines the life.

A tie performs three principal functions:

(a) Acts as a beam to distribute the load,
(b) Acts as a block to transmit the load from rail to ballast,
(c) Holds the rails in place.

It is, therefore, required to possess beam strength, crushing strength and ability to hold fastenings. As between the three, the beam strength is fundamental, because, if deficient in any given tie, there is no remedy, whereas a deficiency in crushing strength or ability to stand compression across the grain can be remedied by suitable tie plates and the ability to hold fastenings modified by the design of the fastenings.

As between different kinds of timber, the strength can be said to vary with the specific gravity. Table II has been prepared from data contained in Bulletin 556, U. S. Department of Agriculture (Forest Service). The modulus of rupture is used by your Committee as indicating relative beam strength for any given cross-section of tie and the compression perpendicular to the grain at elastic limit as indicative of relative bearing strengths. Diagrams A and B show graphically how the modulus of rupture and the compression at elastic limit vary with the specific gravity. It is to be noted that the modulus of rupture varies about as the first power of the specific gravity and that the compression varies, for tie timbers selected, about as the 2.6 power.

Under the assumptions that the mechanical life of a tie is proportional to its strength, which seems reasonable in view of the surplus strength when new feature, and that the strength is proportional to the specific gravity, Table III has been prepared. Another assumption made in preparing this table is that the relative resistance of various woods to decay is constant for variations in climate.

Effect of Size and Tie Plates.

The replies to the Committee's questionnaire indicated a general belief that ties 7 inches by 9 inches would outlast ones 6 inches by 8 inches when subjected to the same conditions. The replies would, perhaps, average 25 per cent. The data given in the questionnaire relative to ties failing by decay shows an average of 30 per cent. greater life for the 7 inch ties, plated, over the 6 inch ties and 20 per cent. for the 7 inch ties, unplated, over the 6 inch ties. These check the opinions fairly well. It is also found that the value of the tie plate in the case of 6 inch ties is 12 per cent., and the case of the 7 inch ties 21 per cent. All of these percentages must be considered only approximate, due to the character of the data. The greater value of the tie plate in the case of 7 inch tie may be ascribed to the fact that the 7 inch ties are, in general, used under heavier traffic.

Annual Cost.

Diagrams C and D have been prepared from the formula recommended by this Committee for ascertaining annual cost. They are self-explanatory.

Applications of Data.

The following examples will indicate how the information contained in this report may be applied:

Example 1. In a location where white oak ties costing $1.50 in track have been in use, and where they have failed largely through mechanical wear in an average of six years, how much more or less per year will chestnut ties at $1.25 in track cost? Referring to diagram C, it is found that the white oak ties are costing 30½ cents per year (6 per cent.). Referring to Table III, it is found in column six that chestnut ties have a mechanical life compared with the white oak as 50 is to 75, or four years. As per diagram C, this would result in a cost of about 36 cents per year.

Example 2. In a location where white oak ties exposed to light traffic fail by decay in six years, and where the traffic is such that failures are about equally divided, decay and mehanical, cedar ties costing $1.25 in track have been in use. How much could be paid for Douglas fir ties, in order that the cost per year would be the same as for the cedar ties? According to column 10 of Table III the cedar ties should average 69 or 5.5 years. As per diagram D (7 per cent.) the cost per year is 28 cents, and Table III for Douglas fir, column 10, gives an average life of 51 or 4.1 years. As per diagram D, the Douglas fir ties should cost about 97 cents each, in place.

Conclusions.

Tie life data does not exist from which satisfactory conclusions may be reached on the subjects assigned. Information lacking is partly as follows:

(a) Actual life data with the conditions of use recorded completely enough to permit satisfactory comparisons between results on different railroads.

(b) Information as to how the "average" life reported is obtained.

(c) Information as to whether the relative resistance to decay of various woods is independent of climate.

(d) Information as to whether the best decay resisting tie untreated is also the best decay resisting tie when treated, whether treatment results in the addition of a uniform number of years life to all kinds of timber, or more to some kinds than others, or whether it results in giving all kinds of ties the same average life under the same conditions.

(e) How mechanical strength is related to resistance to mechanical wear.

(f) How mechanical strength varies with time in track, i. e., from the condition new to the condition when decay necessitates removal.

Recommendations.

(1) The inclusion of the standard test tie in all test installations, for the purpose of comparison, as more particularly outlined above.

(2) The adoption of white oak ties, grade 3, (6" x 8") class U, untreated, 8 feet long as standard for test purposes.

(3) Laboratory test of the mechanical properties of tie timber, which has been subjected to contact with the soil for varying periods under conditions similar to those to which ties are subjected in track. Such tests should develop the relationship between strength and time exposed to the tie destroying agencies other than traffic.

TABLE I—COMPARATIVE LIFE, FAILURES MORE THAN 50 PER CENT DECAY, ALL TIES UNTREATED—WHITE OAK TAKEN AT 100

Based on Returns Contained in A. R. E. A. Bulletin 232					Based on Forest Service Bulletin 118, Page 44	Independent Tabulation Made by an Individual Railroad of the Serviceability of Ties Used in Studies of Economy
Ties 6" Thick		Ties 7" Thick		Average of Cols. 1 to 4	All Sizes of Ties—Untreated	Untreated Ties, Light Traffic.
Tie Plated	Not Tie Plated	Tie Plated	Not Tie Plated			
Black locust 247	Cypress 122	Black locust 181	Cedar 145	Black locust 214	250	
Cedar 200	Princess pine 115	Cedar 170	Chestnut 117	Cedar 156	138	
Walnut 148	Cedar 109	Walnut 160	Walnut 114	Walnut 141		Heart, 150-Sap, 120
Redwood 148	Fir 103	Cypress 133	Larch 96	Heart pine 130		
Cypress 133	White oak 100	Redwood 117	Cypress 94	Cypress 121	125	Heart, 120-Sap, 50
Heart pine 130	Larch 90	White oak 100	Cherry 90	Princess pine 115		
Jack pine 102	Jack pine 90	So. yellow pine 91	So. yellow pine 82	Redwood 112	150	
White oak 100	Ash 82	Chestnut 85	Fir 72	Chestnut 101	88	Heart, 140-Sap, 120
Fir 99	Beech 77	Fir 85	W. Y. pine 72	White oak 100	100	Heart, 120-Sap, 100
Larch 93	Birch 77	Mulberry 85	Redwood 72	Jack pine 96		
Spruce 86	Hemlock 64	West. yellow pine 85	Spruce 72	Fir 90	(Douglas) 75	Heart, 80-Sap, 30
So. yellow pine 74	West. yellow pine 64	Spruce 85	R. or B. oak 48	Larch 90		60
Elm 68	Spruce 64	Larch 80	Loblolly pine 36	Cherry 90		
Gum 64	Tamarack 64	Gum 64		Mulberry 85		
Ash 62	So. yellow pine 62	R. & B. oak 50		Spruce 77	75	
Beech 62	Gum 58	Hackberry 32		So. yellow pine 77	(LL) 88	Heart, 120-Sap, 30
Hemlock 62	R. & B. oak 56	Honey locust 32		Ash 72		
West. yellow pine 62	Maple 51	Loblolly pine 32		West. yellow pine 71	63	
Tamarack 62	Loblolly pine 38	Butternut 21		Beech 70	50	40
Birch 58				Elm 68		30
Loblolly pine 56				Birch 68		20
R. & B. oak 54				Hemlock 63	63	40
Maple 43				Tamarack 63	63	
Sycamore 37				Gum 62	38	20
				R. & B. oak 51	50	50
				Maple 47	50	Hard, 40-Soft, 20
				Loblolly pine 41	38	
				Sycamore 37		20
				Hackberry 32		30
				Honey locust 32		30
				Butternut 21		20
				Hickory		30

Table II—Relation Between Specific Gravity, Beam Strength and Rail Bearing Strength of Timbers Used for Cross-Ties

Kind of Timber		Table I, Bulletin 556, U. S. Dept. Agriculture			Comparison, with white oak taken as 100		
		Specific Gravity	Compression perpendicular to grain, elastic limit	Modulus of rupture, static bending	S. G.	C.	M. R.
			Lb. per sq. in.	Lb. per sq. in.			
Oak-canyon, live	Quercus chrysolepis	.70	1480	10600	117	178	128
Hickory-pignut	Hicoria glabra	.66	1140	11700	110	137	141
Locust-black	Robinia pseudacacia	.66	1430	13800	110	172	166
Hickory-mockernut	Hicoria alba	.64	1000	11100	107	120	134
Gum-blue	Eucalyptus globulus	.62	1020	11200	103	123	135
Oak-Spanish (lowland)	Q. pagodaefolia	.61	940	10800	102	113	130
Locust-honey	Gleditsia triacanthos	.60	1420	10200	100	171	123
Hickory-pecan	Hicoria pecan	.60	960	9800	100	116	118
Oak-white	Q. alba	.60	830	8300	100	100	100
Oak-cow	Q. michauxii	.60	710	8500	100	86	102
Oak-post	Q. minor	.60	1060	8100	100	128	98
Birch-sweet	Betula lenta	.59	520	8600	98	63	104
Elm-cork	Ulmus racemosa	.58	750	9500	97	90	114
Oak-bur	Q. macrocarpa	.58	840	7200	97	101	87
Oak-chestnut	Q. prinus	.57	660	8000	95	80	96
Maple-sugar	Acer saccharum	.56	750	9100	93	90	110
Oak-willow	Q. phellos	.56	750	7400	93	90	89
Oak-laurel	Q. laurifolia	.56	710	7900	93	86	95
Oak-water	Q. nigra	.56	770	8900	93	93	107
Oak-red	Q. rubra	.56	730	7700	93	88	93
Oak-scarlet	Q. coccinea						
Oak-yellow	Q. velutina	.56	870	8200	93	105	99
Pine-longleaf	Pinus palustris	.55	600	8700	92	72	105
Birch yellow	Betula lutea	.54	450	8600	90	54	104
Beech	Fagus atropunicea	.54	610	8200	90	74	99
Oak-pin	Q. Palustris						
Ash-blue	Fraxinus quadrangulata	.53	990	9600	88	119	116
Oak-Spanish (highland)	Q. digitata	.52	680	6900	87	82	83
Ash-white (forest grown)	Fraxinus americana	.52	800	9100	87	96	110
Walnut-black	Juglans nigra	.51	600	9500	85	72	114
Oak-California black	Q. californica	.51	890	6200	85	107	75
Pine-shortleaf	Pinus echinata	.50	480	8000	83	58	96
Pine-loblolly	Pinus taeda	.50	550	7500	83	65	90
Tamarack	Larix laricina	.49	480	7200	82	58	87
Elm-slippery	Ulmus pubescens	.48	510	8000	80	61	96
Maple-red	Acer rubrum	.48	520	7800	80	63	94
Larch-western	Larix occidentalis	.48	560	7500	80	67	90
Hackberry	Celtis occidentalis	.48	490	6500	80	59	77
Birch-paper	Betula papyrifera	.47	300	5800	78	36	70
Mulberry-red	Morus rubra						
Pine-pitch	Pinus rigida	.47	510	6700	78	61	81
Cherry-black	Prunus serotina	.47	440	8000	78	53	96
Gum-black	Nyssa sylvatica	.46	600	7000	77	72	84
Gum-cotton (tupelo)	Nyssa aquatica	.46	590	7300	77	71	83
Sycamore	Platanus occidentalis	.46	450	6500	77	54	78
Ash-black	Fraxinus nigra	.46	430	6000	77	52	72
Douglas fir, coast	Pseudotsuga taxifolia	.45	530	7800	75	64	94
Elm-white	Ulmus americana	.44	390	6900	73	47	83
Gum-red	Liquidambar styraciflua	.44	460	6800	73	55	82

TABLE II—CONCLUDED

Kind of Timber		Table I, Bulletin 556, U. S. Dept. Agriculture			Comparison, with white oak taken as 100		
		Specific Gravity	Compression perpendicular to grain, elastic limit	Modulus of rupture, static bending	S. G.	C.	M. R.
			Lb. per sq. in.	Lb. per sq. in.			
Maple-silver	Acer saccharinum	.44	460	5800	73	55	70
Sassafras	Sassafras sassafras	.42	460	6000	70	55	73
Cypress-bald	Taxodium distichum	.44	470	6800	70	57	82
Douglas fir, mountain	Pseudotsuga taxifolia	.40	450	6400	67	54	77
Chestnut	Castanea dentata	.40	380	5600	67	46	68
Pine-jack	Pinus divaricata	.39	380	5400	65	46	65
Pine-lodgepole	Pinus contorta	.38	310	5500	63	37	66
Hemlock-eastern	Tsuga canadensis	.38	500	6700	63	60	81
Pine-western yellow	Pinus ponderosa	.38	340	5200	63	41	63
Cottonwood	Populus deltoides	.37	240	5300	62	29	64
Poplar-yellow or tulip	Liriodendron tulipifera	.37	310	5600	62	37	67
Catalpa	Catalpa catalpa						
Butternut	Juglans cinerea	.36	270	5400	60	33	65
Spruce-white	Picea canadensis	.36	270	5400	60	33	65
Redwood	Sequoia sempervirens						
Cottonwood-black	Populus trichocarpa	.32	200	4800	53	24	58
Cedar-western red	Thuja plicata	.31	310	5200	52	37	63
Cedar-white	Thuja occidentalis	.29	290	4200	48	35	51

Table III—Untreated Tie Service—100 = 8 Years

Kind of Wood Untreated	Decay Failures: Climatic Conditions Such That Under Light Traffic, White Oak Ties Fail by Decay in 6 Years	Decay Failures: … in 8 Years	Decay Failures: … in 10 Years	Mechanical Failures: Traffic Conditions Such That Failures of White Oak Are All Mechanical in 4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	Failures Partly Decay and Partly Mechanical: Climatic Conditions Such That Under Light Traffic, White Oak Ties Fail by Decay in 6 Years	… in 8 Years	… in 10 Years	Relative Life of Ties: Per Cent	Years
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	250	20
													200	16
Black Locust	150	200	250	55	69	83	96	110	124	103	128	153	188	15
Cedar	112	150	188	25	31	38	44	50	56	69	88	107	175	14
Walnut	105	140	175	43	53	64	74	85	96	74	92	109	163	13.1
Redwood	98	130	163	30	38	45	53	60	68	64	80	97	150	12.0
Heart Pine (Compact Wood)	90	120	150	45	56	68	79	90	*101*	68	83	*98*	120	9.6
Cypress	90	120	150	35	44	53	61	70	79	63	78	*93*	110	8.8
Chestnut	83	110	138	34	42	50	59	67	75	59	72	*86*	100	8.0
White Oak	75	100	125	50	63	75	*83*	*100*	*113*	63	75	*88*	95	7.6
Douglas Fir (Coast)	64	85	106	38	47	56	*66*	*75*	*84*	51	62	*72*	90	7.2
Larch (Tamarack)	60	80	100	40	50	60	*70*	*80*	*90*	50	60	*70*	85	6.8
Ash	53	70	88	43	*54*	*65*	*76*	*87*	*98*	48	*57*	*66*	80	6.4
Sap Pine (Compact Wood)	53	70	88	43	52	*62*	*73*	*83*	*93*	48	*57*	*66*	75	6.0
Beech	53	70	88	45	*56*	*68*	*79*	*90*	*101*	49	*58*	67	70	5.6
Elm	49	65	81	48	*61*	*73*	*85*	*97*	*109*	48	*57*	*65*	65	5.2
Birches	49	65	81	45	*56*	*63*	*79*	*90*	*101*	47	*55*	*63*	60	4.8
Hemlock	49	65	81	33	39	47	*55*	*63*	*71*	41	49	*57*	55	4.4
Gums	45	60	75	39	*48*	*58*	*67*	*77*	*87*	42	*50*	*57*	50	4.0
Red Oak	41	55	69	*47*	*58*	*70*	*81*	*93*	*105*	*44*	*51*	*58*	45	3.6
Maples	34	45	56	*37*	*46*	*55*	*64*	*73*	*82*	*36*	*45*	*55*	40	3.2
Sap Pine (Coarse Wood)	30	40	50	*33*	*41*	*49*	*57*	*65*	*73*	*32*	*37*	*42*	35	2.8
Sycamore	26	35	44	*39*	*48*	*58*	*67*	*77*	*87*	*33*	*37*	*42*	30	2.4
Honey Locust	23	30	38	*50*	*63*	*75*	*88*	*100*	*113*	*37*	*40*	*44*	25	2.0
Butternut	19	25	31	*30*	*38*	*45*	*53*	*60*	*68*	*25*	*28*	*31*	20	1.6

Italics indicate cases where decay rather than mechanical destruction may determine the life of the tie under the climatic conditions indicated in columns 1, 2 or 3.

This table has been prepared under the assumption that the mechanical life of a tie is proportional to its mechanical strength, as indicated by its specific gravity, and that the relative resistance of various woods to decay is independent of climate. **Tie plates are assumed, when required, in accordance with average practice.** This assumption of tie plates is intended to care for the situation where a hardwood tie fails by decay and under the same conditions a softwood tie, unplated, would fail mechanically. It is recognized that this assumption would not always hold good.

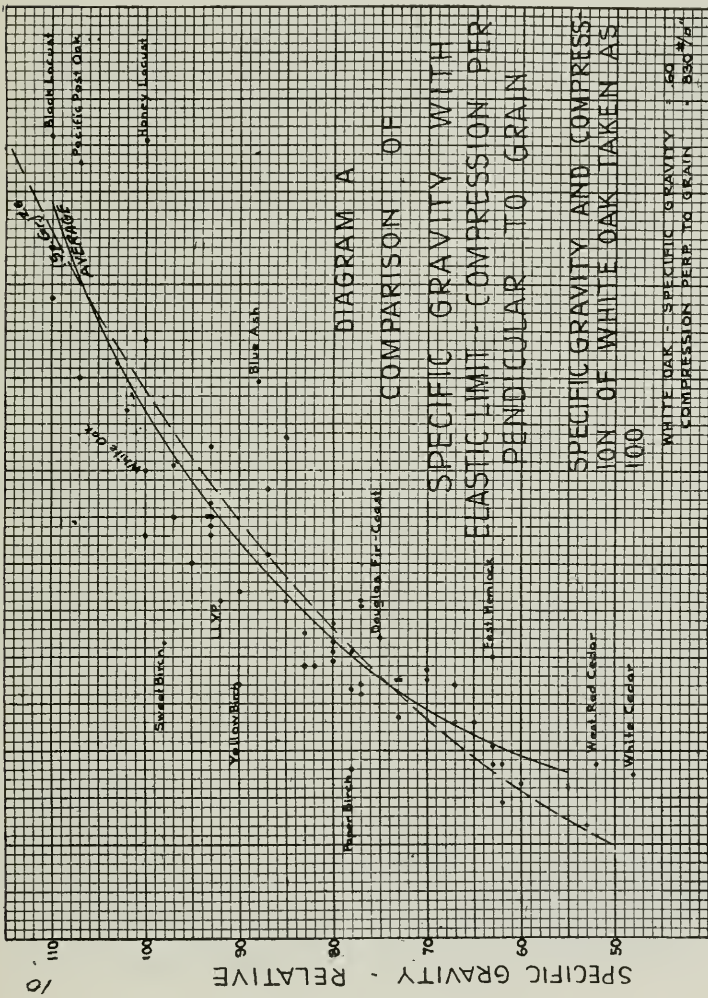


DIAGRAM A
COMPARISON OF
SPECIFIC GRAVITY WITH
ELASTIC LIMIT - COMPRESSION PER-
PENDICULAR TO GRAIN
SPECIFIC GRAVITY AND COMPRESS-
ION OF WHITE OAK TAKEN AS
100
WHITE OAK - SPECIFIC GRAVITY = .60
COMPRESSION PERP TO GRAIN = 830#/□"
Black Locust
Pacific Post Oak
Honey Locust
Blue Ash
White Oak
AVERAGE
Sweet Birch
L.L.Y.P.
Yellow Birch
Douglas Fir-Coast
East Hemlock
Paper Birch
West Red Cedar
White Cedar
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
COMPRESSION PERPENDICULAR TO GRAIN
110 100 90 80 70 60 50
SPECIFIC GRAVITY - RELATIVE

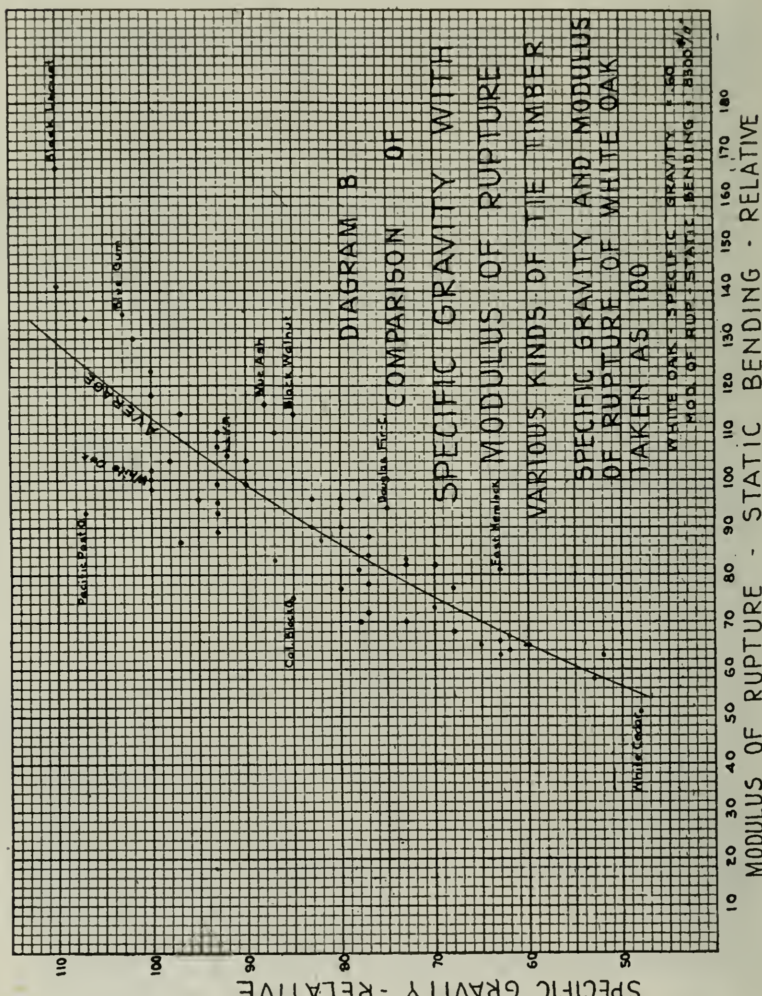
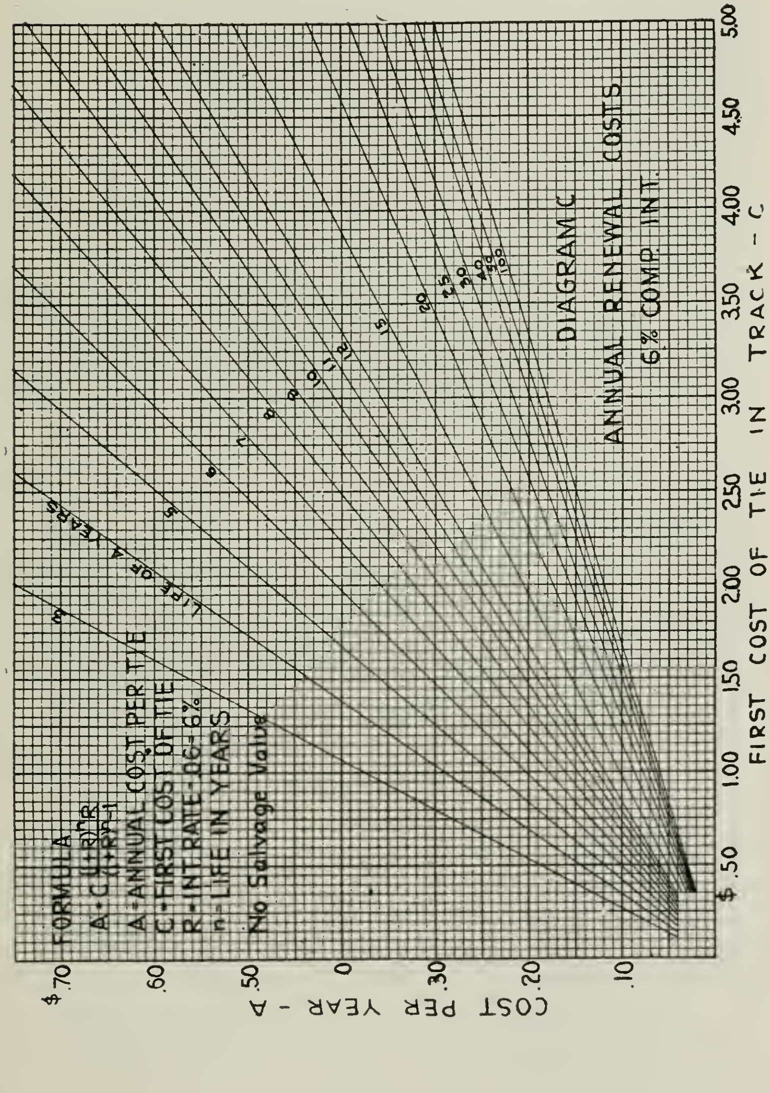
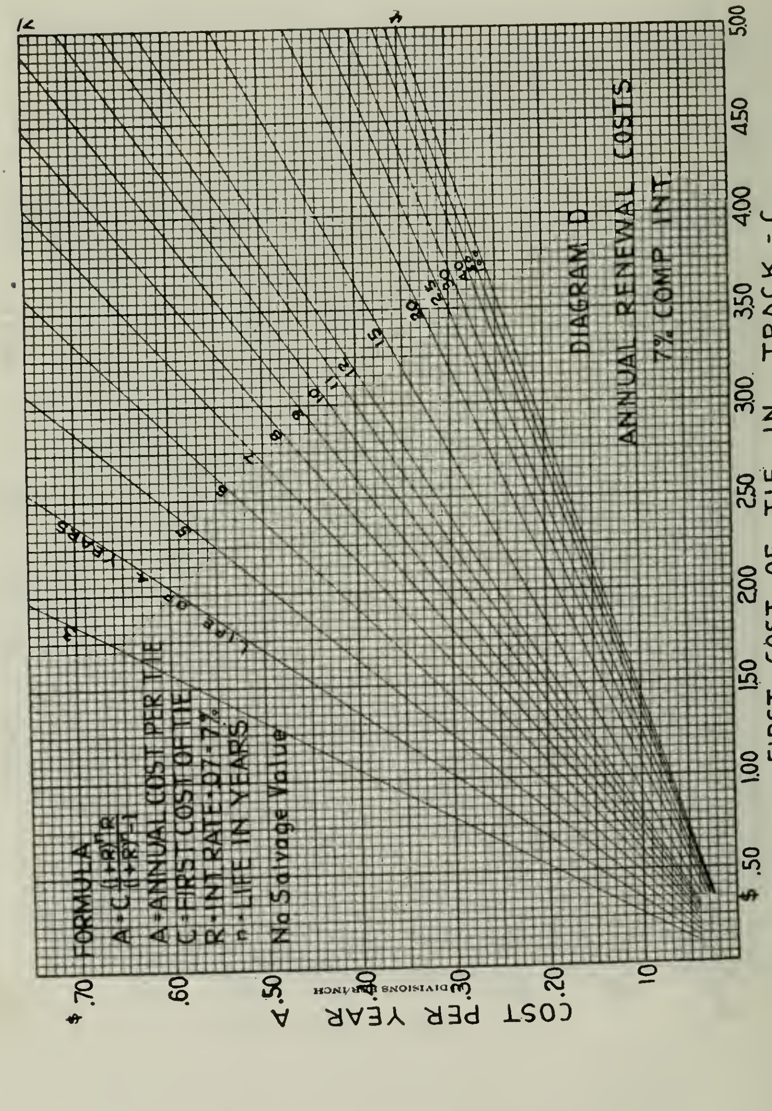


DIAGRAM B
COMPARISON OF
SPECIFIC GRAVITY WITH
MODULUS OF RUPTURE
VARIOUS KINDS OF TIE TIMBER
SPECIFIC GRAVITY AND MODULUS
OF RUPTURE OF WHITE OAK
TAKEN AS 100
WHITE OAK - SPECIFIC GRAVITY = .60
AVERAGE
Black Locust
Blue Gum
Pacific Post O.
White Oak
Nut Ash
Black Walnut
Douglas Fir
Col. Black O.
East Hemlock
White Cedar
MODULUS OF RUPTURE - STATIC BENDING - RELATIVE
SPECIFIC GRAVITY - RELATIVE
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
110 100 90 80 70 60 50


FORMULA
A = C(1+R)^n R / (1+R)^n - 1
A = ANNUAL COST PER TIE
C = FIRST COST OF TIE
R = INT RATE .06 = 6%
n = LIFE IN YEARS
No Salvage Value
LIFE OF A YEARS
DIAGRAM C
ANNUAL RENEWAL COSTS
6% COMP. INT.
COST PER YEAR - A
$.70
.60
.50
.40
.30
.20
.10
FIRST COST OF TIE IN TRACK - C
$.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00


FORMULA
A=C (1+R)^n R / (1+R)^n-1
A=ANNUAL COST PER TIE
C=FIRST COST OF TIE
R=INT. RATE .07=7%
n=LIFE IN YEARS
No Salvage Value
DIAGRAM D
ANNUAL RENEWAL COSTS
7% COMP. INT.
FIRST COST OF TIE IN TRACK - C
COST PER YEAR A
$ .70
.60
.50
.40
.30
.20
.10
$ .50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00

Appendix B

SUBSTITUTE TIES

L. J. Riegler, *Chairman;* E. W. Boots, S. B. Clement, *Sub-Committee.*

There has been very little activity as regards substitute ties during the past year. The test installations as a rule are being continued, but a few have been discontinued. The Committee has no record of any new tests started during the year, but reports upon three installations not heretofore reported upon.

Munslow Steel Ties.

Twenty-seven of these ties were placed in the single main track of the Wheeling & Lake Erie Railroad, east of Jewett, Ohio, in September, 1916. The ties are illustrated on this page and are made of steel pipe pressed into shape, or pressed directly from plates. These ties were put in gravel ballast and supported 90-lb. A.S.C.E. rail, on tangent track and a one per cent. grade. In 1918 the rail was changed to 90-lb. R.B. with a narrower base requiring filler plates between the edge of the flange and fastening device. The ties are subject to a rather heavy traffic and to high speed passenger service.

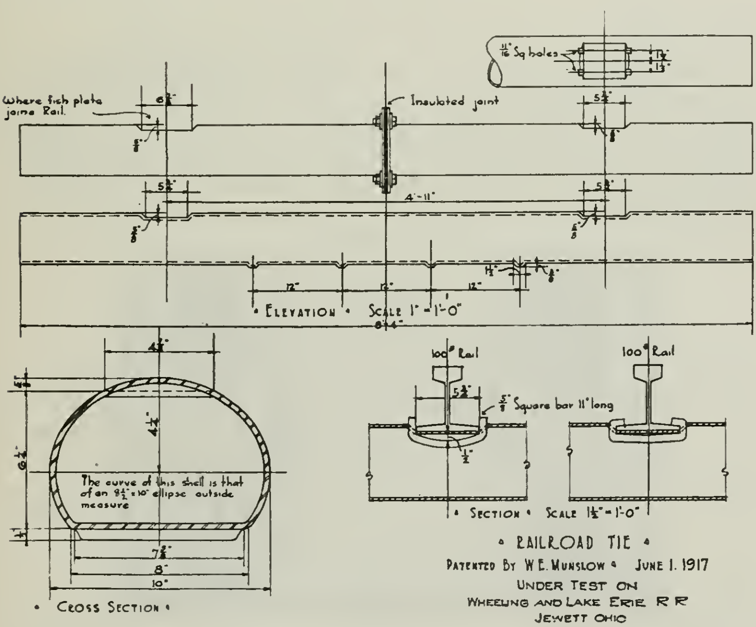


Fig. 1

In the Spring of 1920, twelve of the ties were removed, due to weakness in the tie where the rail is supported. This installation is further reported upon in the reports from railways.

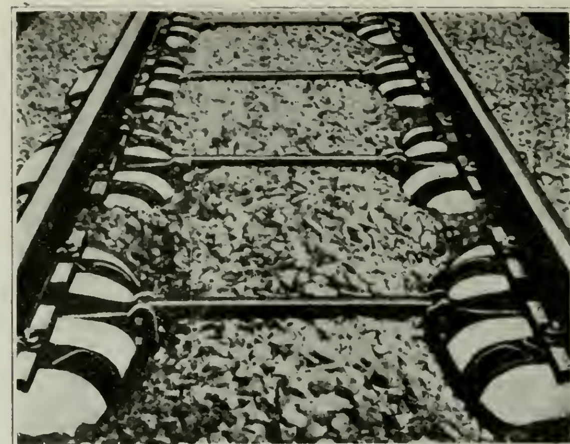


FIG. 2

Silver Tie.

Five of these ties were installed in No. 8 main track of the New York Central at Spuyten Duyvil, New York City, in July, 1918. These ties are made of cast steel and filled with concrete. Wooden blocks are placed between the rail and the metal part of the tie, and the bolts, holding the rail on these wooden blocks, are insulated. Figs. 2 and 3 fully illustrate the construction of the tie.

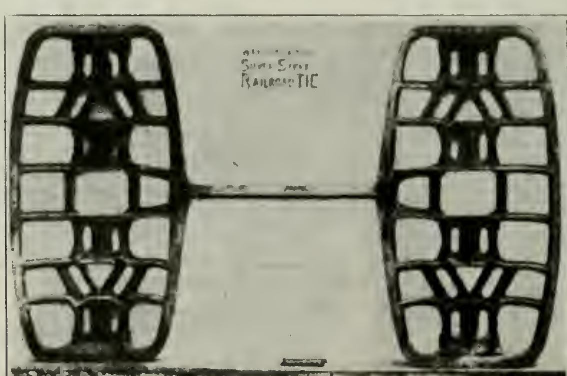


FIG. 3

Kimball Concrete Tie With Concrete Sub-Base.

The Pere Marquette Railway laid about 3,400 feet of track with these ties on a concrete base at Bay City, Michigan, in 1901 and 1902. The ties consist of two concrete blocks under the rails connected with each other by two 3-inch channels and all embedded in the concrete foundation of the street and track. 3-in.x12-in.x15-in. hard wood planks are interposed between the concrete block and the rail base for spiking. The ties supported 75-lb. rail which was changed in 1914 to 90-lb. rail, at which time about 50 per cent. of the wood blocks were renewed. The ties are illustrated in Fig. 4. The ties are subjected to a slow speed passenger service.

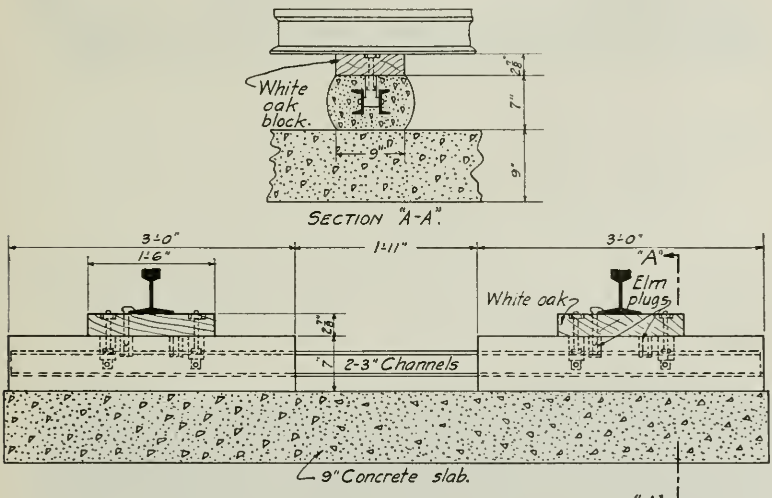


Fig. 4

The Committee again calls attention to the desirability of extensive tests of substitute ties and urges that railroads provide adequate facilities for making such tests. A list of tests now under way is shown on following pages.

Following are reports from railways upon which tests are being made:

Baltimore & Ohio.

Kind—Metal Tie Co.
Reported by—Earl Stimson, Chief Engineer Maintenance.
Date—August 25, 1921.

We still have in track at Martinsburg, W. Va., 50 steel ties made by the Metal Ties Company. The ties are in good condition, with the exception of 20 of the wooden blocks, which will be renewed this year. The blocks are not decayed but have become split, and it will be necessary to renew them. (See Fig. 5.)

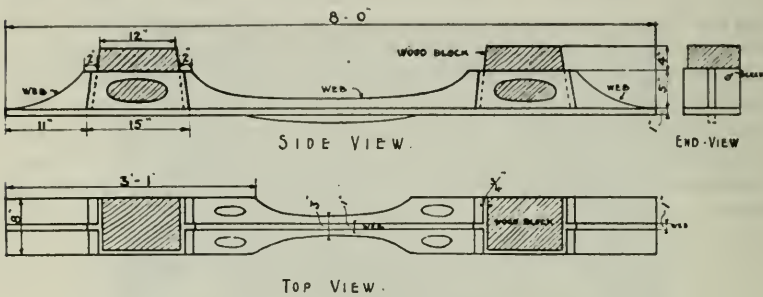


FIG. 5

Bessemer & Lake Erie.

Kind—Carnegie.
Reported by—H. T. Porter, Chief Engineer.
Date—September 20, 1921.

We have purchased no new steel ties this year, and have nothing new to report at this time. The steel ties which are now in track continue to give satisfaction under the conditions existing on this road.

Buffalo, Rochester & Pittsburgh.

Kind—Carnegie.
Reported by—E. F. Robinson, Chief Engineer.
Date—July 5, 1921.

No substitute ties now in track. Of 3,000 placed in track in 1906, 1,500 were removed in October, 1911, account of change of line, and the remainder in September, 1918, account of being worn out. A few were replaced at stand pipes where wooden ties are destroyed by hot cinders from ash pans, but all have now been removed from track.

Delaware, Lackawanna & Western.

Kind—Standard Steel Ties, Hardman.
Reported by—A. J. Neafie, Prin. Ass't Engineer.
Date—August 19, 1921.

Twenty Standard Steel Ties installed at Dover, N. J., were removed from track in October, 1920. The ties were removed account of the wooden blocks splitting and the metal being eaten away.

Thirty Hardman ties were installed in track at East Dover, N. J., on December 4, 1918. The ties are made from sections of wood bound together with strips of metal and treated with asphalt. The construction is illustrated in Fig. 6, and a photograph of the installation is in Fig. 7.

Eight of the ties have thus far been removed account of loosening of the bands and decay. The ties are beyond a doubt proving very unsatisfactory.

Duluth & Iron Range.

Kind—Carnegie.
Reported by—W. A. Clark, Chief Engineer.
Date—July 19, 1921.

During 1917-1918 all of the ties in mile 79 were removed because of damage due to derailments at that point. In 1920 eighteen ties on mile 96

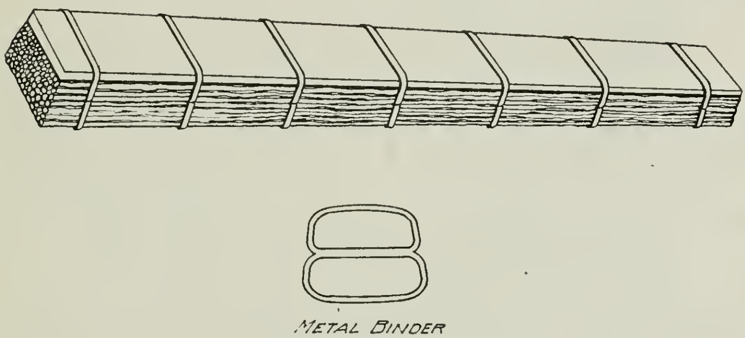


FIG. 6

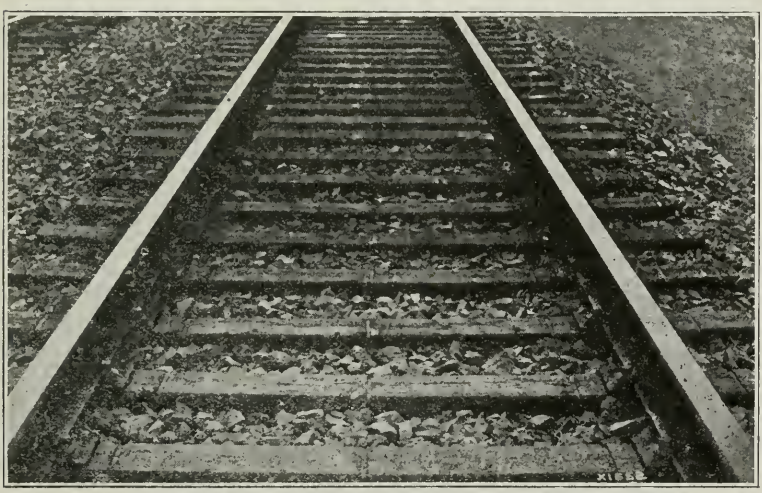


FIG. 7

were removed because of crushing down of the web. Of 2,000 ties installed in 1905, the number now in service is as follows:

At Two Harbors, with experimental patent fastenings....	28
On Mile 96..	600
On mile X-1½..	56
On mile X-1¾..	575
Total	1,259

A few of the above are more or less damaged and will need to be removed before another year.

Duluth, Missabe & Northern.

Kind—Carnegie, Kimball.
Reported by—W. H. Hoyt, Chief Engineer.
Date—July 29, 1921.

Carnegie Steel Ties: Of the 22,380 ties installed in 1908 and 1909, there have been removed 10 in 1918, 64 in 1919, 121 in 1920, or a total of 195, leaving 22,185 still in track.

Kimball Steel Ties: The 30 ties installed in 1914 are still in track.

Elgin, Joliet and Eastern.

Kind—Bates, Carnegie.
Reported by—Arthur Montzheimer, Chief Engineer.
Date—September 9, 1921.

Bates Ties: No change since report for 1920.

Carnegie Ties: We have installed 14,962 Carnegie Steel cross ties at various times, beginning in 1909, of which 1,624 were removed, leaving 13,338 still in track. The number removed is as follows: 1916, 50; 1917, 260; 1918, 182; 1919, 453; 1920, 306; 1921, 373; total, 1,624.

Florida East Coast.

Kind—Percival.
Reported by—H. N. Rodenbaugh, Chief Engineer.
Date—July 13, 1921.

Percival Concrete Ties: All of the ties installed at St. Augustine in March, 1906, were removed from track in December, 1920, on account of changing of 70-lb. rail to 90-lb. rail. This was due to the inflexible method of fastening rail to ties. The condition of the ties at time of removal was perfectly satisfactory, and they, no doubt, would have been good for several years' further service under normal conditions.

Lake Erie & Western.

Kind—Buhrer.
Reported by—J. K. Conner, Chief Engineer.
Date—July 2, 1921.

No change to report. Still have five Buhrer concrete ties in track at Tipton, Ind., installed in August, 1903.

Long Island.

Kind—Carnegie, Combination Concrete and Steel.
Reported by—J. R. Savage, General Superintendent.
Date—July 16, 1921.

Carnegie Ties: Of the 30 ties installed at Hicksville in May, 1909, there are 18 remaining. Six were removed on July 5, 1921, due to their inability to hold track in proper alignment.

Combination Concrete and Steel: Of the 34 ties installed at Long Island City, 8 are still in service but in poor condition, and it is expected it will be necessary to remove them within a short time. If they had been installed at any other point they should long since have been removed, but they are safe for the very slow movement made over the track in which they are installed.

Los Angeles Railway.

Kind—McDonald.
Reported by—B. H. Eaton, Engineer Way and Structures.
Date—July 25, 1921.

Of the 4,323 ties installed at Los Angeles in July, 1911, 4,283 are still in service. Forty ties were removed on Broadway at Tenth Street on account of new construction.

New York Central.

Kind—Silver.
Reported by—Francis Boardman, Division Engineer.
Date—September 13, 1921.

Five of these ties were placed in No. 8 main track of the New York Central at Spuyten Duyvil, New York City, in July, 1918. These ties are made of cast steel covered and filled with concrete. Wooden blocks are placed between the rail and the metal part of the tie and the bolts holding the rail on these wooden blocks are insulated. Figs. 2 and 3 fully illustrate the construction of this tie.

The ties are still in service. The concrete on the outside of the steel frame is cracked in a number of places and has partially fallen off. The track is located next to the Hudson River and normal corrosion has taken place on the steel bolts and other exposed metal parts of the tie. The ties are subject to a slow speed freight traffic only, about fifteen trains, or an average of six hundred seventy-five cars pass over them daily.

Pennsylvania System—Eastern Region.

Kind—Champion, Maryland, Standard.
Reported by—W. G. Coughlin, Chief Engineer M. W.
Date—August 22, 1921.

Champion: Of 995 ties installed at Lenover, Pa., in June, 1920, all are in good condition.

Maryland—Lenover, Pa.—All removed August, 1920. Too weak for the traffic. Broke under the rail. Original installation September, 1919, was 25 ties. These ties were described and illustrated on page 369 of A.R.E.A. Bulletin No. 232, December, 1920.

Standard Steel Ties—Lenover, Pa.—All removed June 30, 1921. Too weak for the traffic. Ends bent upwards and split through the bottom. The 5/16-inch ties lost 37 per cent. and the 3/8-inch ties 14 per cent. by corrosion. Original installation June, 1915, 100 5/16-inch ties and 400 3/8-inch ties.

Pennsylvania System—Central Region

Kind—Carnegie Steel Switch Ties, Mechling and Smith Steel Ties, Riegler Concrete Steel Ties, Snyder Composite Ties.
Reported by—W. D. Wiggins, Chief Engineer M. of W.
Date—November 21, 1921.

Carnegie Switch Ties—Eight sets put in, October, 1911, in Pitcairn Yard. Prior to 1921, 90 per cent. were removed due to being damaged by derailments. In 1921 the remaining 10 per cent. were removed due to being badly corroded and bent.

Mechling and Smith Steel Ties—100 put in track October, 1910, in Wilkinsburg Yard. Twenty removed in 1915 due to bad condition of wood blocks, 11 removed in 1919 due to being damaged by a derailment, 8 removed in 1920 due to poor condition of wood blocks, 46 removed in 1921 due to condition of wood blocks being so bad that gauge could not be maintained, 15 still in track and in poor condition.

Riegler Concrete Steel Ties—15 put in track May, 1908, in No. 1 westward passenger track, west of Emsworth, Pa., transferred to No. 3 eastward freight track in December, 1914. June 7, 1921, two were removed due to concrete being crushed under rail. These ties have been repaired and will be put back in track. An inspection was made September 20, 1921. In three additional ties the concrete was found to be crushing under the rail. A derailed car has damaged a number of bolts used for holding the rail, which bolts will be renewed soon.

Snyder Composite Ties—821 put in track October, 1907, in Derry Yard and none have been removed to date. 1,600 put in track October, 1907, in Conemaugh Yard. Between 1914 and 1916, 280 were removed on account of being damaged by derailments and on account of extension to interlocking. In 1921, 223 were removed due to clips and bolts being so badly rusted that the fastenings could not be tightened. At both locations the ties and fastenings are rusting badly and as the bolts become very loose the ties are removed.

Pere Marquette.

Kind—Kimball.
Reported by—A. L. Grandy, Chief Engineer.
Date—August 20, 1921.

These ties have given very satisfactory service since they were installed in 1901 or 1902. They consist of two concrete blocks under the rails and connected with each other with two 3-inch channels and all bedded in the concrete foundation of the street and track. There is a 3-in.x12-in.x15-in. hardwood plank interposed between the concrete block and the rail base for a cushion and for spiking. Seventy-five-pound rail was laid in this track when it was built in 1902, and was replaced with 90-lb. rail in about 1914. The same ties were retained, but possibly 50 per cent. of the blocks were removed at that time. The pavement was also relaid. The track is now in good condition.

The traffic is confined to passenger trains running not to exceed 10 miles per hour. Fig. 4 illustrates this tie. About 3,400 feet of track is laid with these ties, including the concrete sub-base.

Pittsburgh & Lake Erie.

Kind—Atwood, Standard.
Reported by—A. R. Raymer, Chief Engineer.
Date—August 10, 1921.

Atwood Concrete Ties—The five ties placed in No. 4 main track at McKees Rocks are still in place and giving good service, except for the fastenings, which will soon have to be replaced or the ties removed.

Standard Steel Ties—Of the twenty ties installed in westward main track at Glassport, Pa., on May 4, 1914, all are still in place. They are located on a tangent and are giving satisfactory service. The steel portion appears to be in good condition, and shows no signs of bulging or flattening out. It will be necessary to renew the wood block fillers soon.

Pittsburg, Shawmut & Northern.

Kind—Carnegie.
Reported by—J. N. Thompson, Superintendent M. of W.
Date—July 21, 1921.

Of the original installation of 795 ties, 155 remain in track. Since the last report, it has been necessary to remove 395 ties due to web crushing. They are failing fast now and it is probable all will have been removed within one more year.

Riverside, Rialto & Pacific.

Kind—Wolf.
Reported by—Arthur McGuire, Ass't Chief Engineer.
Date—July 15, 1921.

No change from report of 1920. The ties are installed at Riverside, California, and are not subject to heavy traffic. Only about twenty-nine street cars and two switch engines with trains of not more than twenty cars pass over them daily.

Southern Pacific.

Kind—Goodlett.
Reported by—W. H. Kirkbride, Engineer M. of W. & S.
Date—September 3, 1921.

Of twenty-seven of these ties installed in 1917, only six remain in track; twenty-one were removed on July 22, 1921, because they were in such a broken and cracked condition that they would not hold gauge of track. Of the six remaining in track, two will have to be removed soon.

Southern Pacific Lines in Louisiana.

Kind—Percival, Moore Concrete.
Reported by—R. M. Glover, Superintendent.
Date—July 7, 1921.

Percival Concrete Ties—Of 100 ties installed in track at Bayou Sale in January, 1910, 26 were removed prior to 1919 in connection with track changes, one for inspection purposes and one because of having cracked at

A

a screw spike socket due to a rock having fallen into the socket. The remaining 72 ties were removed in January, 1921. These ties were cracked on the bottom directly under the rail, a distance of about 3½ inches to 4 inches towards the top of the tie. No ties now remain in track.

Moore Concrete Ties—Forty of these ties were installed in main track within yard limits at Lafayette, La., on January 31, 1917. They are subject to heavy traffic but not to high speed. One tie broke in two after one day's service and one tie was taken out in February, 1917, for inspection. Thirty-eight are still in track, of which one is entirely disintegrated and the others in more or less bad condition on account of broken and chipped ends and loose rail fastenings. The tie is illustrated in Fig. 8.

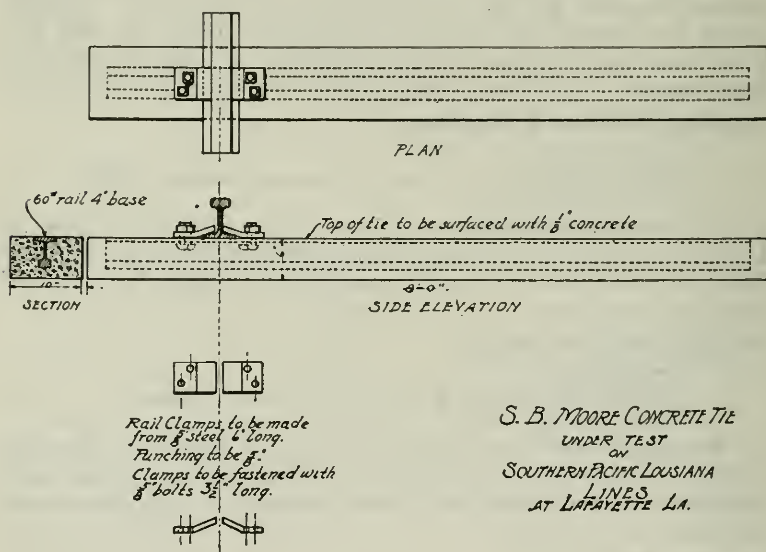


Fig. 8

Southern Pacific Lines in Texas.

Kind—Indestructible, Percival.
Reported by—H. M. Lull, Chief Engineer.
Date—August 27, 1921.

Indestructible—All of the ties installed in May, 1916, are still in track. Inspection on August 9th shows that they are apparently in the same condition as when installed.

Percival—Of 50 ties installed in test No. 1 in October, 1906, three ties were removed account of derailment, four for inspection purposes, and thirty-two account failures in tie or fastenings. Eleven ties remain in track.

In test No. 2 thirty ties remain in track out of fifty-two placed in October, 1906, twenty-two ties having been removed account of failure in tie or fastenings.

Terminal Railroad Association of St. Louis.

Kind—Chamberlain.
Reported by—H. J. Pfeifer, Chief Engineer.
Date—July 12, 1921.

Chamberlain Concrete Ties—The ten ties put in track at St. Louis in April, 1920, are still in service. They have cracked to a considerable extent but not sufficiently to make their removal necessary, as they are in a slow speed track.

Wheeling & Lake Erie.

Kind—Munslow Steel Tie.
Reported by—John Sesser, Engineer Maintenance.
Date—October 7, 1921.

Twenty-five of these ties were installed on September 15, 1916, in the main track about one-quarter of a mile east of Pennsylvania Crossing of Jewett, Ohio. The ties are hollow, made of $\frac{5}{16}$-inch steel plates 8½ feet long and about ¾-inch wide, weight about 200 lbs. When pressed into shape the ties have a bearing surface of 8 inches on bottom.

The ties support 90-lb. rail in slag ballast, 1 per cent. grade, tangent track. Traffic is heavy, about twenty trains per day passing over these ties. Maximum speed is fifty miles per hour.

Twelve ties were removed in March, 1920, account of developed weakness in the metal under the rails. Of the ties remaining, eleven are broken and will have to be replaced.

Tests of Substitute Ties Now in Progress

Railroad	Name of Tie	Location	Number Now in Track	Number Put in Track	Date Put in Track
A. T. & S. F.	Baird	Newton, Kans	No report	3	March, 1910
	Bronson	Chillicothe, Ill		11	Dec. 1914
	Carnegie	Newton, Kans		46	Sept. 1914
	Hanna	Rivera, Calif		8	Nov. 1912
	La Guna	Vegala, Calif		46	July, 1917
	Universal	Florence, Kans		106	June, 1912
Baltimore & Ohio	Metal Tie Co.	Martinsburg, W. Va.	50	50	May, 1909
Bessemer & Lake Erie	Carnegie	Various	Many	Many	Jan. 1905 and subsequent
C. C. C. & St. L.	Carnegie	Greensburg, Ind	No report	1 mile	....
Cornwall & Lebanon	Snyder	Mt. Gretna, Pa	No report	206	1906
D. L. & W.	Hardman	East Dover, N. J.	22	30	Dec. 4, 1918
Denver & Salt Lake	Shane	Denver, Colo	No report	13	Oct., 1912
	Shane	Denver, Colo	....	13	Aug., 1916
Duluth & Iron Range	Carnegie	Various	1,259	2,000	1905
Duluth, Missabe & N.	Carnegie	Duluth & Proctor, Minn	22,185	22,380	1908–1909
	Kimball	Virginia, Minn	30	30	1914
Elgin, Joliet & Eastern	Bates	Whiting, Ind	62	62	May, 1912
	Carnegie	Various	13,338	14,962	Various
Huntington & B. T. M.	Stoneback	Huntington, Pa	No report	3	April, 1915
Lake Champlain & Moriah	Carnegie	....	No report	48	....
Lake Erie & Western	Buhrer	Tipton, Ind	5	5	August, 1903
Long Island	Carnegie	Hicksville, N. Y.	18	30	May, 1909
	Comp. Concrete and steel	Long Island City	8	34	1911–1912
Los Angeles Ry.	McDonald	Los Angeles, Cal.	4,283	4,323	July, 1911
New York Central R. R.	Silver	Spuyten Duyvil	5	5	July, 1918
Pennsylvania R. R. Eastern Region	Champion	Lenover, Pa	995	995	June, 1920
Central Region	Mechling & Smith	Wilkinsburg, Pa	15	100	Oct. 1910
	Riegler	Emsworth, Pa	15	15	May, 1908
	Snyder	Derry Yard	821	821	Oct., 1907
		Conemaugh Yard	1,097	1,600	Oct., 1907
Pere Marquette Ry.	Kimball	Bay City, Mich	X	X	1902
Pittsburgh & Lake Erie	Atwood	McKees Rocks, Pa.	5	5	Oct., 1908
	Standard	Glassport, Pa	20	20	May, 1914
Pittsburg, Shawmut & Northern	Carnegie	Byrndale Branch	155	795	Summer of 1907
Riverside, Rialto & Pacific	Wolf	Riverside, Cal	58	60	Oct., 1913
Southern Pacific	Goodlett	Oakland, Cal	6	27	Nov., 1917
So. Pacific Texas Lines	Indestructible	Eagle Pass, Texas	23	23	May, 1916
	Percival	Edwater, Texas	11	50	Oct., 1906
		Edwater, Texas	30	52	Oct., 1906
Southern Pacific Louisiana Lines	Moore	Lafayette, La	38	40	Jan. 31, 1917
Union Railroad	Carnegie	Pittsburgh, Pa	No report	5,000	1908
Term. R. R. Assn. of St. L.	Chamberlain	St. Louis, Mo	10	10	April, 1920
Wheeling and Lake Erie	Munslow	Jewett, Ohio	15	27	Nov., 1916

X—3,400 lin. ft. of track.

Appendix C

EFFECT OF DESIGN OF TIE PLATES AND TRACK SPIKES ON THE DURABILITY OF CROSS-TIES, AND RESULTS OF IMPROPERLY PROTECTING TIES FROM MECHANICAL WEAR.

M. S. Blaiklock, *Chairman;* F. Boardman, G. F. Hand, A. J. Neafie, *Sub-Committee.*

This subject has been assigned since 1912 and the following reports have been made:

Year 1913—Vol. 14—Page 728

The report developed the extent of the use of flat and flanged tie plates, the size of tie plates in general use, the extent of use of cut and screw spikes and an opinion as to tie plate bearing area and distance plate should extend outside base of rail.

Year 1914—Vol. 15—Page 726

The report developed the effect on the tie of different features in the design and application of the plates and spikes as determined from a canvass of twenty-nine (29) railroads. It covered the damaging effect of tie plates of insufficient width and thickness or having deep ribs or claws, damaging effect of cut spikes and prolongation of life of tie by use of screw spikes rather than cut spikes, and desirability of boring ties for spikes before treatment. Appendices were attached as follows:

"A"—Comparative holding power of spikes.
"B"—Cut spikes vs. screw spikes.
"C"—Photographs showing the effects of tie plates and spikes on ties from studies on the A. T. & S. F. Ry.

Year 1916—Vol. 17—Page 233

The report illustrates tendencies of good practice as regards rail fastenings in their effect on ties, and calls attention to the desirability of reducing or eliminating, if possible, movement between tie plate and the tie. Information is given as to size of tie plates and spikes used on certain railroads, with photographs of several designs used by the D. L. & W. R. R.

Year 1917—Vol. 18—Page 475

The report developed the cause of failure to protect the tie and reached certain conclusions respecting proper design of tie plates. Appendices were attached illustrating tie failures on the D. L. & W. R. R. and the development of the tie plate on the Penna. R. R.

Year 1919—Vol. 20—Page 226

The report made a study of the relative effect of cut and screw spikes on the durability of the tie and expressed the following opinions:

1. That there is not sufficient data available, due to lack of general use, to show that the use of screw spikes will increase the durability of ties except under special conditions.
2. That there may be specific forms of track construction where screw spikes prolong the life of ties, such as on elevated structures and so-called permanent track where there is more substantial foundation provided than on ordinary tie and ballast track.

YEAR 1920—VOL. 21—PAGE 580

The report deals with the screw spike and gives what, in the opinion of the Committee, is good practice in regard to a screw spike installation.

It is the purpose of this report to briefly summarize the conclusions arrived at which, in our opinion, continue to represent good practice. The principal effects of different kinds of tie plates and spikes on the tie have been described in previous reports and are matters of general knowledge.

It would be uneconomical to use material and labor in protecting the cross-tie from mechanical wear beyond what is necessary to prevent the tie failing from this cause before it has to be renewed because of decay or other reasons. It is impracticable to make an attachment between the tie and the rail it supports without in some degree injuring or distorting the fiber of the wood, and any safe method of attachment is satisfactory which does not limit the life of the tie so that it has to be removed account of spike killing or mechanical wear before its strength is exhausted because of decay. The use of preservatives which increase the life of the tie very greatly from a decay standpoint has justified additional expense in protecting the tie from mechanical destruction, and this has brought about the use of larger and stronger tie plates and improved methods of spiking. It should be borne in mind that the safety and cost of maintenance of the track depend largely on the continued efficiency of the connection between rail and tie, and the dictates of good practice in design of fastenings are the same whether from a tie protection standpoint or a track maintenance standpoint.

Tie Plates—Effect of Design.

The following features should be provided for to ensure a minimum of damage to the tie:

a. Adequate strength and area to prevent buckling and excessive settlement in the tie. The required bearing area and thickness will be governed by the kind of wood and character and amount of traffic. The distances the plate extends beyond either side of the rail base should be so proportioned as to prevent uneven settlement of the plate into the tie and consequent rolling of the rail. Allowance should be made for the deterioration of the tie plate which will normally take place, particularly near salt water or where there are brine drippings.

b. It is important that the tie plate have a shoulder to maintain gage, so that the thrust from the rail is transmitted to the tie through the bearing area of the tie plate and the spikes as a unit, instead of being directly resisted by any spike.

c. There should be no movement between the tie plate and the tie. The effect of any looseness is to make a "track which rattles," causing damage to the plate bearing area of the tie and enlargement of the spike holes. This close connection between tie plate and tie can best be accomplished by the use of separate fastenings which do not touch the rail and whose only function is holding down the plate. The ordinary means is to provide projections on the bottom of the tie plate; these should be deep enough to provide the required bond and to do their part in strengthening the tie plate, but so shaped and of a depth to do as little damage as possible to the tie, and it is believed that the depth of such projections should not exceed $\frac{3}{16}$-inch, and be so shaped as not to cut the fiber of the wood. When screw spikes are used, a rest shoulder should be provided on which the screw spike bears when driven home, leaving a freeway between the rail base and the under side of the spike head; this aids in making the bond between tie plate and tie. The freeway between the underside of the spike head and the rail base is of great importance and should be from $\frac{1}{16}$-inch to $\frac{3}{16}$-inch, depending on character of the subgrade.

Spike—Effect of Design.

Safe and good track can be obtained by use of either screw spikes or different forms of cut spikes, and the choice between these is purely a question of which is more economical, all things considered; there is no evidence at this time that the screw spike in itself prolongs the life of the tie. The early installations of screw spikes in this country were defective as regards the design of the spike and its application, but this has been corrected in later work and in a few years there should be more accurate information on this question. Spikes should be in accordance with the standards of this Association. (Cut spike—Vol. 22, p. 653. Screw spike—Bulletin 197, p. 32.) The design of the screw spike is of great importance in its effect on the tie. The thread on the spike must be accurate in dimension and pitch (made to fit gages as recommended by the Association Standard), and so made in conjunction with a leader that the spike can be easily started in the hole in the tie by a light tap from a hammer. These features are provided for in the Association Standard, and failure to observe them results in destruction of the screw threads in the wood either in the initial application of the spike or in replacing spikes when renewing rail. The necessary freeway between the screw spike head and the base of the rail should be secured through the design of the tie plate.

Method of Application.

The surface of the tie should have an accurate bearing surface to receive the tie plate; this is best accomplished by machine adzing. There is considerable advantage in prolonging the life of the tie by boring holes to receive the spikes; this is, of course, necessary to the application of screw spikes. If cut spikes are used the expense of boring untreated ties is not warranted, but all treated ties should be bored for spikes if the maximum life of the timber is to be secured. Such holes should preferably be bored entirely through the tie to ensure adequate depth when the tie plate has settled into the tie.

When treated ties are used all adzing and boring should be done before treatment. In case it becomes necessary to bore any holes in treated ties in the field, as in the case of switch ties, or to use tie plugs, the holes should receive an application of preservative before the spike or plug is applied. All tie plugs used in treated ties should be treated.

Attention is called to the danger of over-spiking. When the number of spikes is sufficient to hold the rail and gage properly, any additional spiking unnecessarily injures the tie at the most critical point. Additional spikes may be driven when actually required.

REPORT OF COMMITTEE XXIII—ON SHOPS AND LOCOMOTIVE TERMINALS

F. E. MORROW, *Chairman;*
A. T. HAWK, *Vice-Chairman;*
C. N. BAINBRIDGE,
G. W. BURPEE,
LELAND CLAPPER,
W. H. COOKMAN,
GEORGE H. GILBERT,
WALTER GOLDSTRAW,
E. M. HAAS,
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G. W. HARRIS,
E. A. HARRISON,
L. P. KIMBALL,
W. T. KRAUSCH,
M. A. LONG,
J. B. MADDOCK,
J. W. PFAU,
L. K. SILLCOX,
JOHN SCHOFIELD,
L. L. TALLYN,
A. M. ZABRISKIE,

Committee.

To the American Railway Engineering Association:

(1) **Revision of Manual:** The proposed changes and additions to the Manual are given in Appendix A, report on Ash Pits, and Appendix B, report on Engine Houses.

(2) **Ash Pits:** The report and recommendations of the Committee are given in Appendix A.

(3) **Engine House and Power Plants and Shop Extension—Collaborating with Division V—Mechanical.**

In collaborating with Division V—Mechanical, this subject has been divided into several parts. The report and recommendation of the Committee with respect to Engine Houses are given in Appendix B.

The Committee reports progress with respect to Engine Terminal Layouts, as shown in Appendix C.

(4) **Car Shops:** The work of the Committee this year has been confined to Passenger Car Shops, and the Committee reports progress as shown in Appendix D.

(5) **Coaling Stations:** Committee reports progress.

(6) **Typical Layouts for Storage and Distribution of Fuel Oil:** Committee reports progress.

(7) **Storehouses:** Committee reports progress.

(8) **Outline of Work for Ensuing Year:** Committee recommends the re-assignment of all subjects except Subject No. 2—Ash Pits.

CONCLUSIONS

Your Committee recommends that the findings and conclusions of the Sub-Committee on Subject No. 2—Ash Pits, as embraced in the summary of Appendix A, be adopted and placed in the Manual in lieu of the material now appearing in the Manual under this subject.

Your Committee recommends that the findings and conclusions of the Sub-Committee on Engine Houses, as shown in Appendix B under recommended changes in Manual, be adopted and placed in the Manual.

Your Committee recommends that the reports on Engine House Layouts and Car Shops, as shown in Appendices C and D, be accepted as information only and incorporated in the Proceedings.

Respectfully submitted,

COMMITTEE ON SHOPS AND LOCOMOTIVE TERMINALS.

F. E. MORROW, *Chairman.*

Appendix A

ASH PITS

G. H. GILBERT, *Chairman;*
C. N. BAINBRIDGE,
LELAND CLAPPER,
R. J. HAMMOND,
F. E. MORROW,
Sub-Committee.

General

When a railroad engine terminal fails to turn serviceable power promptly and economically, much of the trouble is often due to delay in handling engines over the ash pit. This has created a popular impression that there is something radically wrong with ash pit design. Upon being assigned the subject of ash pits, your Committee undertook the study without prejudice and with open minds, hoping to conclusively establish such facts as would discredit poor designs and lead to definite conclusions and recommendations. After two years' investigation and consideration of a great deal of data generously furnished by the railroads of the country, your Committee is led to believe that most of the dissatisfaction with ash pits is not due to the types of pits in use, but to the way in which they are operated or to the fact that many of them are entirely outgrown and inadequate to meet changed operating conditions and increase in size of locomotives. The real underlying cause of dissatisfaction seems to be that ash pit layouts and size of operating force are so often fixed by normal demands rather than allowing for abnormal, unusual or extreme demands. In other words, dissatisfaction with ash pit operation will continue to exist until railroad managements recognize the economic importance of first-class ash pit service under all the varied operating conditions as related to the economic use and movement of engines and traffic as a whole.

Nearly every type of ash pit in common use is favorably recommended by the officials of some roads and shows low operating cost under certain conditions, while adversely commented upon by other officials and showing high operating cost under other conditions. This reflects the different demands of engine terminals varying as they do from those handling a few engines per day to those handling several hundred per day and also shows a deal of difference in the personal equation.

From the submitted data it is evident that the selection of a proper ash pit for any certain terminal should be determined almost wholly by conditions peculiar to the railroad and to that terminal. This makes it impossible for your Committee to present a condensed set of conclusions or recommendations for adoption and printing in the Manual, but there is offered a summarized statement of all essential information which has been developed, a brief discussion of various features essential to all designs, and such general recommendations as it is thought can be properly supported, especially recommendations indicating the size of terminals for which any certain type of pit seems most suited. This "Summary" is recommended for adoption and printing in the Manual. Some subject matter contained in it has been omitted from the main body of this report to avoid needless repetition.

Practically all railroads of the United States and Canada were requested to furnish the following information regarding ash pits:

1. Essential description of principal types used with blue prints showing cross-section, length and track layout.
2. Statement regarding number of locomotives handled over such pits per day and per rush period of two hours, together with statement regarding normal forces employed day and night with rates of pay.
3. Approximate estimates of cost of construction at 1919 prices and average cost of maintenance per annum.
4. Statement of advantages and disadvantages of each type with recommendations as to its use in new construction.

The replies received from the railroads failed to develop a deal of information sought by the Committee, but the essential facts of such data as was received is shown in tabular form in the Proceedings, Volume 22, pages 622 to 647, inclusive.

Types of Ash Pits

Considering the subject of ash disposal in its broadest aspects, including all handling of ashes from locomotive ash pans, methods of disposal and ash pits actually in use may be conveniently considered and discussed in classes or groups as given below:

1. Ashes are discharged directly onto ordinary track and thence removed by hand. This is done at some places where only a few engines are handled and where ashes can be wasted by widening fills, but it mainly occurs with engines on line of road between terminals. In some parts of the country where freight runs are long, fires are cleaned two or more times between terminals and even passenger engines under unusual conditions clean fires on line of road. Such cleaning is generally done near water stations, or passing tracks.

While the cleaning of fires on line of road is an operating necessity, it nevertheless involves some risk to traffic unless the practice is properly regulated. Accumulation of packed ashes at planked road crossings and at switches have caused derailments. Such cleaning should be permitted only at designated locations between marked limits and where ashes can receive proper attention. Canadian law prohibits dumping of "fire, live coals or ashes" on "tracks or right-of-way unless they are extinguished immediately."

Where ashes can be wasted over a nearby bank, such removal is economical, provided there is plenty of other work to keep the force busy. Where a depressed loading track can be built at almost no cost for grading and drainage and where old bridge lumber can be used for a low retaining wall, ashes can often be loaded into cars at little extra cost. Such temporary arrangements are to be recommended at some places to take care of helper engines or a few engines at junction points of unimportant branch lines.

2. Ashes are discharged into small shallow pits of non-combustible construction. Some pits have metal ties with 12 to 18 inches of ash storage below base of rail. Most generally the pits are between the rails and from 18 to 30 inches deep of various lengths and provided with hand hose and drainage. Such pits are used at very small terminals or in yards where switch engines would lose too much time running to the terminal ash pit for fire cleaning. Numerous other similar arrangements will be suggested by local physical conditions, particularly where engine track is located on a high bank. In such cases, several small pits can be built under the engine track with one side open next the low ground and small dump cars used on a light level track. Where ashes cannot be wasted with a short haul, but must be loaded into cars, an inclined runway or some simple mechanical aid may be used in loading the ash cars. If much of mechanical equipment seems justified, then consideration should be given to other common types of pits.

The main advantage of these simple pit arrangements is the low cost per engine of handling ashes when proper allowance is made for the cost per engine of investment in ash plant, ash cars and track on which ash cars are placed. Another advantage is due to the possibility of dumping ashes at one time and removing them at any later time that may be convenient.

3. A time-honored ash pit is that with a depressed loading track and with paved pits under the engine tracks, the ashes being removed by shoveling into cars. At some terminals where locomotive cranes are available, ashes are removed with clam shell buckets. A "single" pit has one engine track and one depressed loading track, a "double" pit has two engine tracks with the depressed loading track between. Formerly many such pits were constructed with both rails supported on pedestals, but as men are no longer required to work under engines to clean the fires, such pits are now sometimes built with one rail bearing on a masonry wall and the other rail supported by cast iron or cast steel pedestals. Some roads find the masonry bearing wall to be expensive and difficult to maintain in a safe condition, and recommend that both rails be supported on pedestals with thin curtain walls used between the pedestals on the closed side of the pit. These pedestals are often spaced 30 to 48 inches apart, dependent upon driver wheel loads and form of beam used to support the rail. Single rails without extra support between pedestals are too light for heavy wheel loads. One and two rail supports are made by inverting the rail without riveting to the track rail and by placing bearing castings between two rails and bolting the combination. Sometimes the track rails are supported on I beams, in which case the span generally varies from five to twelve feet and the cast pedestals are more often cylindrical and filled with concrete rather than the common type with ribbed webs. These pedestals are securely anchored to masonry and the pit is paved generally with either fire brick or vitrified brick on a concrete base. The retaining wall next the depressed track should be raised slightly above the top of the paving to prevent ashes washing over it, and should be pro-

vided with drainage holes, unless drainage is obtained by sloping the pavement in the reverse direction, as is sometimes done. The vertical distance from top of rail of depressed track to level of edge of paving should be about five feet. This height does not require a large investment for the depressed track and retaining wall and yet provides for easy shoveling of ashes into such cars as are generally assigned to ash pit service. Some hopper bottom cars measure 10 ft. 8 in. above top of rail and where such cars are apt to be used, an increase in height of the retaining wall may be desirable. Suitable drainage must be provided for the depressed track, which is a feature that generally gives a deal of trouble. The amount of normal ash storage afforded by this type of pit depends upon length of pit, depth from base of rail of engine tracks to pavement and upon the number of cars that can be placed on the loading track. One road secures additional storage by using two depressed tracks between the two engine tracks. With either labor trouble or failure to switch loaded cars, the amount of ash storage is immediately reduced to that which can be dumped into the pit from the engines. Where many engines are handled, this can never be much more than enough to take care of rush periods without shoveling. Practical handling usually requires that even during rush hours, one of more men be kept continuously busy shoveling. Depth of pit should not be less than three feet and preferably four feet. Greater depths will result in a decided increase in construction costs and in added length of depressed track. Those who recommend this type of pit point out the following advantages:

(a) No skilled labor is required.
(b) Maintenance does not affect service, as repairs are restricted to replacement of pedestals and rail supports with spare parts, or else to repairs of pavement which can readily be made without impairing service.
(c) Pit can be operated in all kinds of weather if labor be available.
(d) Loaded cars do not freeze so solidly as with water pits.
(e) Construction cost compares favorably with that of other types of pits.
(f) Where fire cleaners would be idle a great part of the time, their use to load cinders does not add to the total cost and the cost per engine may therefore be as low as with other types of same cost of construction.

The disadvantages are:

(a) Unskilled labor under recent industrial conditions is seldom required to do so dirty, hard and disagreeable work as is normally necessary at a busy pit of this type. In stormy weather, or during extreme cold or heat the working conditions are about as severe as labor will stand even when labor is plentiful and afraid of losing work. Moving in section forces to clean these pits is no very unusual occurrence.

(b) The quick cleaning of engine ash pans makes it desirable to have standing room or a platform on each side of the engine at the track level which is an impracticable arrangement on the open side of this type of pit.

(c) Uniform operation at the larger terminals requires switching of ash cars practically as soon as loaded, which almost never suits other yard work. In some locations, it is possible to place several empties on a track and drop the cars as they are loaded, the same as at coal tipples, but this is exceptional.

(d) At the very time that proper operation of ash pit is most essential to train movements in periods of congestion, extreme weather conditions, etc., there is more liability of interrupted service due to the labor element, limited ash storage space, car shortage and lack of switching. This occurs, too, when supervising officials should be free to handle other pressing troubles.

(e) When so many engines are handled that added men are required just to load the ashes, the cost of operation is apt to be higher than for other types of pits.

4. Water pits are of two general classes, which are conveniently designated as shallow water pits and deep water pits. They are used with terminals handling from forty to several hundred engines per day. Shallow pits are long pits three and a half to four feet wide and about four feet deep, constructed between the rails. Deep water pits are usually nine to thirteen feet in depth, constructed to give a large amount of ash storage and arranged for removal of ashes from outside the engine track. Both kinds of pits are kept nearly full of water, thus quenching all fire of ashes which drop into them. Ashes are removed by clam-shell buckets operated from either locomotive or overhead traveling cranes; sometimes gantry cranes are used.

Shallow pits are so narrow that they require especially long buckets for reasonable capacity. Such pits are usually arranged in units of three or five tracks spanned by a crane. With the three-track unit, continuous pits are provided for the two outside tracks, while the middle track is used merely as an ash car track. With the five-track unit, pits and ash car tracks alternate similarly. Thus ashes can be removed from any portion of any pit not covered by an engine and loaded into cars without interference with work of cleaning fires of any engine or without carrying ashes above either engines or workmen. Tracks should be spaced not less than fifteen feet center to center based upon the need of good working space for men on the ground between ash cars and adjacent engines. Overhead traveling cranes are usually used with these pits. The pit itself needs to have some metal protection, such as embedded rails, placed on its sides and bottom on account of the scraping action of the clamshell buckets. Drainage should be provided not only near the top of these pits, but also at the bottom to facilitate cleaning them out for inspection or repairs. A sloped pavement is used between tracks draining to the pits over the head of the track rails.

The common arrangement of deep water pits is that of a rectangular double-track pit, with one rail of each track on a side wall and with the other rail on pedestals, the clamshell bucket being operated between the two tracks. One road has many single pits at intervals along one engine track, using the adjacent track on the open side of the pits as an ash loading track, using locomotive cranes. Many other arrangements are possible and good where enough engines are handled to justify and require more extensive and expensive track layout and pit construction. With the usual double track pit, no special ash car track is provided, and therefore ashes can be loaded only when few engines are on the pit so that one engine track can be blocked by the ash cars. In some cases, an ash car track is located adjacent to one side of the pit, all three tracks being spanned by the loading crane. With this track arrangement, the loading of ashes into cars interferes with the handling of engines over the pit only to the extent of providing an open space between engines through which the clamshell bucket may be handled to the ash car. A number of pits have been built with three tracks, the middle track being exclusively an ash car track. This arrangement adds greatly to the cost of construction, which must be justified wholly by the complete lack of interference between the work of cleaning fires and the work of removing ashes.

One road, after a careful study of ash pits, is now constructing a circular form of double-track deep-water pits, which apparently has many advantages, and compares favorably in cost with other pits. It accommodates two engines at a time, one on each of two tracks, and has working platforms or ground space on each side of each engine. Railings remove the danger of men falling into the pits. This type of pit facilitates the flow of ashes to the center of the pit where they are most readily handled by clamshell bucket, and has several advantages in construction. The circular wall resists earth pressure cheaper than can be done with retaining wall sections and favors the use of quite deep pits with ample ash storage without such a large increase in construction costs as would be required with the rectangular form of pit. Again, the outer circular concrete shell or wall can be built above ground and sunk by the so-called "open crib" method, thus saving cost of sheathing, and some yardage of excavation and backfill. The balance of the concrete in foundations and inner walls can be cheaply placed. By the construction of several such pits properly spaced and serving the same two-engine tracks, fully as great engine capacity, and as nearly compact an arrangement, can be obtained as with rectangular pits and, it is claimed, at less cost.

Many deep-water pits have been constructed with rather long spans under the rail between supports, the rail beams consisting of various arrangements of channels and I beams. Such steel rusts and warps badly from the action of heat and the chemicals in the ashes, and unless such beams are protected or removed when necessary, they are apt to fail under some engine. Many kinds of protection have been used which increases the serviceable life of these beams, but none of which present their ultimate replacement. Your Committee believes it would be better practice to space rail supports fairly close together, use bare steel beams, always have spare beams on hand and renew from time to time as necessary. Obviously such beams should have a surplus of strength when first installed.

The big advantage of a deep-water pit is the large amount of ash storage and the resultant dependability of handling engines over the pit.

Some criticism is raised against this type of ash pit on account of occasional accidents resulting from men falling into them. While such accidents are due to utter carelessness, your Committee feels that such safeguards should be provided as are feasible, particularly where there is considerable travel in line with the pit. Various methods have come to the attention of your Committee for safeguarding this type of pit, as follows:

(1) Railings are provided all around the pit except right at the track at the ends of the pit, where engine movement and proper engine side clearances prevent the use of railings. At the tracks, stock-guards, shallow or sloping pits have been used, but they fill up with dirt, snow, ice or cinders, and apparently do little good.

(2) In one instance, wooden rafts have been placed in the water between the tracks, which are removed by the crane to the end or sides when the ashes are taken out. These rafts are apparently not satisfactory, because storage space is not always available, the rafts are often damaged in handling, a hazard to employees is introduced while handling them, and they become water-logged and sink below the surface.

(3) In another instance, sectional steel gratings have been placed between the tracks and rods spaced 9 in. to 12 in. centers between the rails, these rods being wide enough apart for cinders to go through them and not wide enough apart for a man to fall through. This method completely covers the pit so as to prevent accidents, but has not proven wholly satisfactory for substantially the same reasons as in the case of the rafts.

(4) In other instances, sidewalks with railings thereon have been provided along the inside of the tracks. This removes need of care when men step down off engines, and also provides a working platform for fire cleaners. Such platforms with railings connected at the ends of the pit, when well maintained, and used in connection with fixed gratings between the rails of each track, should effectually prevent accidents. However, the use of inside platforms is impracticable unless provided for when a pit was originally constructed, as the space required for operation of the clamshell bucket cannot be reduced. In new construction, such platforms can be provided by using wider track centers and a correspondingly deeper pit to maintain the same flow line of cinders. The cost will be materially increased with rectangular pits, but not a great deal with the circular pits above described.

At all water pits, good lighting is not only necessary for the fire cleaning, but it contributes greatly to safety of employees.

In cold climates, no trouble is generally experienced with freezing of deep-water pits if many engines are handled. However, the ash cars freeze solid and may make unloading very costly if not practically impossible, unless unloaded promptly. Another objection often made to deep water pits is the high cost of construction which really requires that terminal arrangements be definite enough to consider the ash pit investment a permanent one. The shallow-water pit is less costly to construct for equal engine standing room, but such pits are apt to be constructed longer to give the desired ash storage. Shallow pits are cleaned daily during a work period of from four to eight hours, while deep pits are cleaned a few hours per day or every two or three days, depending on size of pit and amount of ashes accumulated.

The better installations of both types of water pits give almost as great dependability of operation as it is possible to get, with low operating cost, provided the ash handling force does not have a deal of idle time and provided enough engines are handled to reduce the fixed charges per engine. Uniform operation depends upon suitable source of electrical power and availability of electrician in case of need if overhead and gantry cranes are used and the availability of an additional locomotive crane, if such a crane is used.

5. Most of the remaining types of ash pits commonly used either have the ashes discharged in a hopper or a series of buckets, from which the ashes are removed to cars by a great variety of mechanical arrangements.

The most generally used ash pit in this group is the "Robertson Conveyor," although during the last few years a very similar ash hoist known as the "N. & W." has also been put upon the market. The essential features of the latter were developed on the Norfolk & Western Railway. Both consist essentially of hoppers discharging into cars which are hoisted by cable on an inclined track and dumped into cars on an adjacent track.

The Robertson Conveyor is installed in single and double units, the latter being required for ash pans with several hoppers or long discharge. It consists of a track opening between the rails about five feet long with ties protected by metal aprons, through which ashes fall into skips, holding about one and one-half cubic yards. The skips are hoisted either by air or electricity on a structural steel frame work which extends over the loading track to supporting metal bent between tracks. The required air pressure is from ninety to one hundred pounds.

The N. & W. conveyor has a cast iron hopper, eight feet long, and nearly two and one-half feet deep, with controlling gate, discharging into a skip holding nearly three cubic yards. It is intended to be used with electric power.

Both of these conveyors have the disadvantage that to meet commercial competition they must be standardized or of fixed dimensions as to area over which they receive ashes, and as to ash capacity of skips, whereas these requirements as given by locomotives in actual use vary over wide extremes of dimensions and capacity. The single Robertson unit should be purchased only when it is known to have sufficient ash capacity. In the double Robertson unit, the small ash skips are normally spaced eight feet center to center, which is very favorable to receive cinders from many different classes of power. For some engines, the hopper of the N. & W. type is too short, but it is entirely long enough for the great majority of engines. If either of these conveyors are installed, the requirements of power in service should be checked. Both lack arrangements for standing room of fire cleaners on one side of the engine.

The advantage of these conveyors lies in low cost and easy work for labor, combined with very little delay in handling engines on account of the feature of loading ashes. However, a mechanical failure makes it necessary to abandon the pit immediately, because there is no storage. The amount of water used to quench fire is under control and cars need not freeze so solidly as with water pits. On the other hand, careless labor will load live ashes and burn cars, which is also true for many other types of pits. Compressed air may give trouble in freezing weather. Again these pits must always have cars into which the ashes can be loaded or the ashes will have to be dumped on the ground, in order not to delay cleaning engine fires. To guard against delay due to lack of switching service, at least two cars should be spotted for each loading point, and where a number of conveyor units are used they should be spaced at least three ash-car lengths apart. This will permit a loaded car to be dropped down and a second car loaded independent of conditions at any other loading point. A suggested track layout has three tracks, engine tracks outside and loading track between, with conveyor unit from each track discharging into the same car. This arrangement is open to the criticism that during switching of ash cars no hoisting with the conveyor can be done unless crossovers are especially arranged to provide for at least two separate operations in switching the ash cars.

A somewhat common ash-handling arrangement has hoppers in each of several tracks and under the hoppers there is a transverse tunnel or chamber in which an ash car is operated. This car or cars receive ashes from the track hoppers, and is then moved to the end of tunnel and hoisted for discharge into cars or similar results are obtained by other mechanical means. In some installations bucket conveyors are used and overhead storage in concrete bins is provided. In others, instead of a single hopper in each track, there are several buckets on separate cars which can be moved and dumped into the hopper or ash car. This type has a peculiar advantage, as it can be used with main tracks for cleaning fires of engines on line of road. It also favors use of multiple tracks either as ash-pit tracks, outbound tracks or open running tracks, according to terminal needs at different times of day.

A few ash plants have a continuous series of ash buckets in long pits between the rails, the buckets being moved under overhead fixed hoists or structures for unloading either directly into cars or into overhead storage bins.

The successful handling of ashes from stationary boilers by means of the suction from a steam jet has led to several similar installations for railroad ash pits. Fairly high pressure is necessary and the steam consumption is great.

Most all of these special arrangements require expensive construction and nearly continuous removal of ashes. Then, again, the operation of such plants generally separates the force of fire cleaners from those removing ashes and thus prevents utilizing the idle time of fire cleaners. Most such plans must be justified by their adaptation to peculiar local operating requirements or to a desire to consolidate several classes of terminal work.

Locomotive Fire Cleaning

Ash pit design and layout must be based upon a correct understanding of the methods used and work done in cleaning locomotive fires. A statement of the essential facts is given in the "Summary" of this report and will be largely omitted here.

The laws of both Canada and the United States require locomotives to be equipped so that ash pans can be emptied without the necessity of any employee going under them. The United States law is known as the Ash Pan Act, approved May 30, 1908. It has the wording "unlawful to use any locomotive in moving interstate or foreign traffic, not equipped with an ash pan, which can be dumped, or emptied and cleaned without the necessity of any employee going under such locomotive." The Canadian law is found in General Order No. 87, Order No. 15988, February 17, 1912, of the Board of Railway Commissioners. Its wording is—"shall equip such locomotives as may be in use with ash pans that can be dumped or emptied without the necessity of any employee going under such locomotive, except in cases of emergency." Another order of this same Board, General Order 107, July 4, 1913, covers the prevention of fires originating on the railroad and contains the following requirements:

(a) Prescribes covering of the openings of ash pans with heavy sheet iron dampers or screen netting dampers, and fastening of same.
(b) Prescribes location and use at certain parts of the year of overflow pipes from lifting injectors for wetting ash pans.
(c) Prohibits employees opening dampers of such engines under certain conditions.
(d) Regulates dumping of fires in the following wording: "No such railway company shall permit fire, live coals or ashes to be deposited upon its tracks or right-of-way, unless they are extinguished immediately thereafter, except in pits provided for the purpose."

Obviously, the actual construction of ash pans, so far as location, dimensions and methods of discharge are concerned, must govern the layout of track, hoppers or pits designed to receive the ash discharge. Numerous representative ash pan plans were secured from leading railroads and from the locomotive manufacturers. These plans show an endless variety of ash pan arrangements, evidently due to need of ash pan capacity under different restrictions as to space and clearance, especially for modern heavy power. Some of these ash pan arrangements are essentially indicated in the accompanying drawing. Types I and II are common examples of those pans that discharge ashes at one point or in one pile. In type II the maximum length of opening reported was 36 inches. Type I requires use of blower, type II covers all single hoppers discharging by gravity. Width of discharge opening for all inside pans is seldom under 20 inches, and often 24 inches. A few plans show 27 inches. Types IV and V illustrate the more common arrangements where ash pans have two hoppers. Numerous other pans are used with two hoppers or two discharge openings. Some gates slide horizontally, some are hinged at the top and others at the bottom. One ash pan really consists of two pans of type I placed one ahead of the other, and both being flushed in the same direction. Another has similar flat slopes to the pan, but flushes in opposite directions. In many the hoppers slope in each direction so that ashes tend to drop vertically while others, even with a gravity discharge, tend to pile up in one direction. For types IV and V the out-to-out length of openings without regard to method of discharge varies from 42 in. to 125 in. and includes such variety as the following: 42 in., 44 in., 48 in., 52 in., 60 in., 64 in., 73 in., 81 in., 90 in., 91 in., 112 in., 125 in. Few plans show over 91 in. Some U. S. R. R. Administration standard plans show about 48 in., on the other hand some heavy engines built in 1918 show 87 in. to 90 in.

Type VIII represents inside ash pans with three hoppers. Apparently there is more uniformity of design with this type than for any other ash pan arrangement. It seems to cover largely recent design approved by the U. S. R. R. Administration. Out-to-out lengths of discharge openings vary from 82 in. to 99 in. Most gate arrangements are of the type shown. Types III, VI, VII and IX show a variety of ash pan arrangements with pans both inside and outside the track rails. The overall length of discharge is from 103 to 115 inches, the overall width is from 106 to 112 inches. Practically no ash pits are planned to receive ashes on the outside of the rails, so that the use of these outside pans, especially with modern engine of large tractive power is a disturbing feature of ash pit design, unless such construction may be considered exceptional. From correspondence with locomotive manufacturers, your Committee believes that outside pans will receive only limited use and that they should not be considered in ash pit design except where actually in use.

From the above data, it is evident that a large railroad system, having a great variety of power, needs to use ash-receiving hoppers of very liberal length, with some extra allowance for spotting engines and for the spread and piling up of ashes beyond the extreme out-to-out lengths of discharge openings. All the power used on any one road may, however, discharge ashes over a very short length, so that at present short hoppers will give as good service as longer ones. Such facts make it difficult for your Committee to present definite conclusions and recommendations for general use throughout the country, and make it much more advisable in this report that information be given and underlying considerations indicated with design to be fixed by local operating requirements.

The amount of ash storage which is possible with any type of ash pit design is fundamentally important to uninterrupted ash pit service and in estimating the capacity of the pits as to number of engines which can be handled during rush periods and per day. The amount of ash per locomotive is dependent upon the kind of cleaning done, grate area of engines, character of coal, and operating features as affecting condition of fire. Obviously real ash pit design must be based upon classes of power in service and tests of ash per engine for the terminal under consideration. A check of 7,013 fire cleanings showed 1.41 cubic yards per engine with a good grade of coal and with the largest power having a grate area of 54 sq. ft. Other reports indicate more ash per engine. Your Committee recommends that at least two cubic yards be allowed per engine for figuring average storage capacity and that for hopper capacity not less than 2½ to 3 cubic yards be allowed for modern engines having 80 or more sq. ft. of grate area.

The capacity of an ash pit in terms of engines handled over it in rush hours is dependent either on its physical size or engine standing capacity or upon the operating force employed. The latter can be changed from time to time to meet varying needs, but physical capacity generally is fixed. It is determined by the time actually required to clean engine fires plus some practical allowance for lost time due to interference from other engine handling or lack of attention. Your Committee desired to make an extensive check of the time actually required to clean fires of various classes of power so as to secure a reliable average figure, but very little data was furnished.

One report may be summarized as follows:

Types of Engine	*Range*		*Average Time*	*Average Number Men*
27x30 Mikado	6 to 26 min.	Fires killed	16.5 min.	2.7
22x30 Consolidation	9 to 29 min.	Fires killed	14 min.	2.1
22x32 Santa Fe	11 to 19 min.	Fires killed	15 min.	3
22x28 Pacific	7 to 17 min.	Fires cleaned	9 min.	2.4
27x30 Mountain Pass.		Fires killed	50 min.	2
20x26 6-Whl. Switching	7 to 10 min.	Fires cleaned	6 min.	2
24x28 8-Whl. Switching	6 to 9 min.	Fires cleaned	7.5 min.	2
20x26 6-Whl. Switching	14 min.	Fires killed	14 min.	2

Another road gives the following:

Type of Engine	*No. of Engines*	*Range of Time Actual Cleaning*	*Average Time Actual Cleaning*	*Average Time on Pit*
Freight	39	7 to 35 min.	15.6 min.	23.2 min.
Mostly passenger and switch, some freight.	135	5 to 75 min.	35 min.	45 min.

Where local data has not been secured, it is suggested that capacity be estimated on the basis of an engine staying on the pit 45 minutes and requiring 30 minutes cleaning by two men. Capacity thus estimated will probably be exceeded in actual operation unless a large part of the power is heavy or there are other unfavorable conditions.

There is no benefit in large ash pit capacity if engines cannot be handled freely to and from the pit. For satisfactory and dependable ash pit service, a well planned and generously proportioned track layout is absolutely essential. The operating demands are given in the "Summary" and will not be stated here except to emphasize the advantage in giving preferred attention to certain engines which can be done readily where there are three or more tracks over the ash pit and to emphasize the absolute need of standing room off the pit, so that engines may be moved forward even though the turntable is in use. Where several separate pits or conveyor units are used, a careful check of the layout should be made for freedom of engine movements, switching of cars and slight movement of loads and empties to avoid need of switching.

Ash pit layouts are built to condition power for revenue service. The greater and more exacting the demands for high class service, the more justification for high cost per engine handled. The most economical ash pit is not necessarily the one of lowest cost per engine, but the one that gives certain required operating service without needless investment or expense. At the same time, the number of engines handled year in and year out at a large terminal make the cost per engine an important consideration. Such cost per engine properly includes operating cost, maintenance, interest on the investment and depreciation or obsolescence. For temporary investments over five to ten years the obsolescence charge may be a material factor in the choice of a pit.

A check of operating payroll costs at quite a number of ashpits of different types, seemed to show no such radical difference in cost per engine as might logically be expected from the different designs. Your Committee then decided to make more extended checks of cost over a 28-day period for each common type of pit. The railroads very generally assisted in making such a check and the results are given in tabular form in Exhibit "A," "Cost of Cleaning Fires and Loading Ashes Into Cars." The reported costs were in response to the following request: "Report total payroll cost due to cleaning above number of locomotive fires and handling ashes into cars. (Do not include supervision, overhead expense, or any maintenance charges for power and upkeep. If men are employed also on other work, include only such part of their wages as is due to cleaning fires and handling ashes.)" Kind of locomotive was requested by cylinder diameter, stroke and wheel arrangement rather than by grate area, as it was thought doubtful if proper reply would be received if grate area were requested and also because grate areas would not indicate class of power to many operating officials.

Careful examination of the submitted costs will show how unwise and unfair it would be to try, with this small amount of data, to draw any conclusions as to the most economical type of ash pit. The lowest cost reported would be increased four times but for employment of forces on other work. The highest cost is due to special service and is not fairly comparable with that at any other terminal. The variation in these reported costs, even for the same type of pit on the same road with similar power, indicates how easy it is for interested parties or those with strong opinions and prejudices, to find plenty of data to support their contentions. In spite of the unfairness of direct comparison, average figures by type of pit are interesting and are here given for what they may be worth.

Average Pay Roll Cost of Cleaning Fires and Loading Ashes Into Cars.

(This data not fairly comparable for reasons given in text.)

Type of Pit	*No. of Terminals*	*No. of Fires Cleaned*	*Average Cost per Engine*
Robertson and N. & W. Conveyor......	14	16,151	80.2c
Deep Water	33	58,729	95.1c
Shallow Water	6	14,205	87.7c
Depressed Track	29	52,020	99.6c
Miscellaneous	13	20,439	117.9c
All Types	95	161,544	97.3c

The unfairness of comparison with cost data at lower labor rates and somewhat smaller engines can be inferred from report of similar costs made in 1915 covering five terminals (two water pits and three depressed track pits) for 7,013 fire cleanings, where the cost was 28.5c, 33.1c, 35.0c, 42.0c and 61.3c, respectively.

The cost of cleaning a locomotive fire so far as discharging the ashes into the pit are concerned is a matter of labor rates, supervision, etc., and may be thought of as independent of the type of pit, or the cost of ash removal into cars. However, if engines do not arrive at a terminal at a fairly uniform rate, the fire cleaners will have much idle time. The use of this time to reduce cost of handling ashes into cars is what helps some types to be economical at small terminals and yet uneconomical at large terminals.. Again, fixed charges, that is, interest on the investment and depreciation or obsolescence, must be divided according to number of engines handled, which makes it very difficult to say one type of pit will add 10 cents per engine for fixed charges and another 20 cents. As an extreme illustration, on one road a double deep water pit about 50 feet long is handling nearly three times the number of engines that use another similar pit over twice as long. The first pit is entirely too small and the second one has ample capacity for the next 15 years. Here the feature of capacity and not type of pit makes a difference in fixed charges per engine of nearly 600 per cent.

So far as selection of type of pit is influenced by low cost per engine, there apparently will always be differences of opinion which can be supported under some conditions and cannot under others.

As discussed more completely in the "Summary," your Committee believes that true economy of railroad operation requires that the ash-handling plant and layout be designed most carefully and liberally, to give required service at all times and under all conditions. Low cost per engine is important, but should not be considered as against reasonable expense to secure dependability of operation and ample excess capacity to care for future growth of traffic or unusual operating demands.

The following "Summary" is submitted as a more complete statement of essential information regarding ash pits and is recommended for adoption and printing in the Manual.

Summary

Ash pits in use at engine terminals throughout the United States and Canada and methods used to remove and dispose of ashes from locomotive ash pans vary greatly. They reflect controlling conditions of an operating, climatic, financial or physical nature, and also show great difference of opinion among those responsible for the selection and construction of ash pit arrangements.

Operating conditions require that nearly all freight engines and, in exceptional cases, passenger engines clean fires and dump ash pans on the road between engine terminals. At the terminals, the number of engines handled varies from a few up to several hundred, and even at large terminals, there is great difference in operating requirements due to character of traffic, number of diverging main lines and proximity to large yards and industrial centers. Freight engines often arrive in "fleets." Engines in passenger and fast freight service require preferred attention to protect train schedules.

Climatic conditions vitally affect the supply and dependability of fire cleaners and ash pit men, who must work in the open in all kinds of weather. Some ash pits fill up with snow or ice in severe winter weather, and cars loaded with ashes freeze so solid as almost to prevent unloading at reasonable cost.

The financial condition of a railroad is often the controlling feature in the construction of ash pit layouts, some railroads being in position to expend considerable sums of money to reduce maintenance and operating costs and to avoid risks to interruption of service, while other roads for financial reasons are compelled to install pits of least first cost. Often facilities for ash disposal have been outgrown, but expenditures for new construction are not warranted until consideration can be given to an entirely new terminal layout. In some cases, operating conditions are not sufficiently definite to justify permanent construction.

Physical conditions at terminals such as topography, nature of foundations available, drainage, cost and character of construction materials and proximity of waste banks are obviously important considerations.

Where personal opinion seems to govern in the selection of an ash pit, the judgment of engineers and operating officials seems to vary most as to:

(a) Method of quenching fires.

(b) The extent to which satisfactory ash pit operation is dependent upon freedom from interference from other terminal operations.

(c) The extent of provisions to assure freedom from breakdown and possibility of continued satisfactory operation under abnormal or unexpected demands.

Types of Ash Pits

Methods of ash disposal and types of ash pits may be classified under six general types or groups as follows:

(1) Ashes discharged directly onto ordinary track construction, and thence removed by hand to waste banks or cars. This method is most generally used with ashes dumped on line of road.

(2) Ashes discharged into shallow pits 12 to 30 inches deep, with the rails supported either on non-combustible walls or on metal ties. This method is used at very small terminals and in some yards located distant from regular engine terminals.

(3) The depressed track pit, where engines discharge ashes onto a platform a few feet below the rails, from which the ashes are shoveled into cars on an adjacent depressed track. This type of pit is in general use throughout the country at terminals handling from a few up to one hundred or more engines per day.

(4) Deep water pits, where ashes are discharged into a pit 8 to 15 feet deep, nearly full of water, from which the ashes are loaded into cars with clam shell buckets operated by various types of cranes. This type of pit is in general use at terminals handling from forty up to three hundred engines per day.

(5) Shallow water pits where the ashes are discharged into long shallow pits constructed between the rails and nearly filled with water, from which the ashes are removed with clam shell buckets operated by overhead traveling cranes. This type of pit is in use at terminals handling from fifty to one hundred and sixty engines per day.

(6) Pits where ashes are discharged into hoppers or a series of buckets, and thence removed by a great variety of mechanical arrangements. Among these in common use are the Robertson and N. & W. types, where the hoppers discharge into skips which are hoisted with cables on an incline track, and dumped into cars placed on an adjacent track. Another common arrangement has an underground chamber or tunnel built transversely to the tracks with track hoppers located above. A small car operates in this chamber to receive the ashes from the hoppers, and is itself operated to the end of the chamber where it is either dumped or hoisted and discharged into an ash car placed on an adjacent track. Most of these special mechanical arrangements are in use at terminals which handle from twenty to one hundred or more engines per day.

When Robertson or N. & W. type conveyors are used, the larger terminals require the installation of several units.

For a more detailed description and discussion of the advantages and disadvantages of these various types of pit, and for a tabulation of seventy-four representative pits in service throughout the country, see Proceedings of 1921, Vol. 22, pages 622 to 647 inclusive.

Locomotive Fire Cleaning

Ash pit design and layout must be based upon a correct understanding of the methods used and work done in cleaning locomotive fires, and the actual operating requirements surrounding such work. The essential facts are as follows:

As locomotives are handled over ash pits, fires may be dumped entirely to allow boiler washing, inspection and repairs or to stand engines "dead," fires may be cleaned and banked so that engines may be quickly placed in service; fires may be thoroughly cleaned and engines, especially switch engines, be returned immediately to service, or fires may be re-cleaned as engines with banked fires leave the engine house outbound to be placed in service. Proper terminal operation requires that all engines have fires cleaned without unavoidable delay, and demands that certain engines, such as switch engines, short turn freight and passenger engines, have fires cleaned immediately following arrival at the ash pit tracks. Usually two men work together cleaning a fire, one man in the locomotive cab shaking the grates, and pulling clinkers out of the fire door, and the other man on the ground, dumping the ash pan. With the larger engines, three men can often work to advantage, and often a fourth man can be used for a few minutes only.

The laws of both Canada and the United States require locomotives to be equipped so that ash pans can be dumped or emptied without the necessity of any employe going under them. With most engines, ashes are dropped by gravity, while with a certain proportion of engines, possibly ten per cent, the ashes are discharged by flushing and blowing them out with water and steam from one or more blowers connected with the boiler. Up on the sides of the ash pans, ashes are apt to pack hard, and these usually have to be pushed and washed down by men working on the ground at the side of the engine. This requires suitable piping for hand hose, although part of the washing is done with the overflow from injectors. Some locomotives have ash pans which discharge ashes both outside and between the track rails, but this is an unusual arrangement, and most engines have only inside ash pans with from one to three hoppers. The width of discharge openings seldom exceeds twenty-four to twenty-seven inches. The length out to out of discharge openings of hoppers varies generally from a few feet up to eight feet, with some engines having a greater length, up to ten feet. Some ash pans discharge on a slope, and ashes pile up beyond the edge of the hopper openings. As a general statement covering the classes of engines in common use, ashes may be said to be discharged from an area two feet wide by ten feet long. Receiving hoppers or pits should be enough longer to properly take care of the spread of the ashes, and to allow for not less than two feet variation in spotting engines.

The amount of ashes per locomotive is a vital feature of design. It varies greatly, according to the grade of coal, local operating conditions, length of run, and proportion of engines with small and large grate areas. It also varies according to the character of cleaning done; that is, the proportion of fires completely dumped to those only cleaned. All real ash pit design requires that the amount of ashes to be handled shall be determined from definite knowledge of the proportion of engines of different types in service, and by real measurements of the amount of ashes from each of the principal types of engines with due regard to future requirements. With such information lacking, the capacity should be based upon not less than two yards, and preferably 2½ yards of ashes per engine; and in the design of skips and hoppers to take all the ashes from any one engine, an allowance should be made of from two and one-half to three cubic yards.

Economy of operation requires that the force of ash pit men be the minimum that will take care of operating requirements during the rush hours, and that during other hours, this force be reduced as much as possible. Unwise efforts at economy often reduce the ash pit force to that number of men required under average conditions rather than under rush hour conditions, so that with many types of ash pits, there is a decided advantage in arrangements which do not require the removal of ashes until the rush hours of fire cleaning are over. This also indicates that a well designed and large capacity ash handling plant, of itself, does not assure quick and satisfactory service if it be not correctly and efficiently manned. From these conditions, it is evident that the features of any proposed ash pit layout should be carefully checked against the requirements of the power actually in service, for the grade of coal used, and for the operating conditions at the local terminal.

Essential Requirements of Ash Pit Designs and Layouts

The essential requirements, and their relative importance, for all ash pits and layout, are as follows:

(1) Capacity for Handling Engines.
(2) Dependability of Operation.
(3) Economy of Operation.

Capacity for Handling Engines

By capacity is meant the ability to satisfactorily meet operating requirements during rush hours as measured by the number of engines which it is possible to handle. Engines arriving at a terminal and waiting to be handled over the ash pits, must not block yard leads and running tracks, block access to water columns, prevent certain engines from receiving preferred handling over the ash pits, or interfere unnecessarily with the switching of ash cars. Engines must be handled over the ash pit soon enough after arrival to allow time for the other terminal work without delaying the dispatching of trains. This must be true not only for the usual rush hours, but there must be enough reserve capacity to take care of the rush hour demands which will arise from whatever increased traffic or congested conditions may arise during the life of the particular ash pit, or else enough room must be left in the layout for a future expansion of ash pit facilities. Mere size or physical capacity of the pit must not be considered separately from that of operation by ash pit forces which would be used, or could reasonably be expected to be used during rush hours. The importance of ample reserve capacity in the plant cannot be overstated. It outweighs all other considerations of type or economy. The failure of ash pit operations to function properly imperils every other feature of train movements, and such failure during periods of abnormally heavy traffic may in itself make the difference between handling a heavy business at great profit or at tremendous loss. Niggardliness in the layout of ash pit arrangements so far as it affects capacity has certainly, in many cases, proved very costly and uneconomical. The following features of track layouts are favorable to quick handling of engines over ash pits and should be provided wherever possible:

(1) At the approach to the ash pits there should be sufficient trackage to stand all engines which may arrive in fleets in rush hours and which cannot be immediately taken care of on the ash pit.

(2) Crossovers and other track connections should be provided, particularly to open yard or running tracks, to make it possible to give preferred attention to any engine regardless of its time of arrival, and to permit switching of loaded ash cars at most any time of day with a minimum interference with movement of engines over the ash pit.

(3) Except at minor terminals, two or more tracks should be provided over ash pits. Where three to five tracks are needed and can be provided, certain tracks often can be used for inbound or outbound engines according to the terminal requirements.

(4) The track layout should be such that engines may be moved off of the ash pit freely so soon as fires are cleaned, regardless of all other terminal work, particularly operations at the turntables. As often all engines on any one track will be moved off the pit at the same time in busy periods of the day, this requires each engine track to accommodate in the clear the same number of engines as constitutes the capacity per track of the pit.

(5) Where possible, track connections should be provided between the ash pit and turntable to allow movement of switch and other engines to clean fires and proceed outbound without using the turntable.

The capacity of an ash pit, as measured by the rate engines can be handled over it in rush hours, obviously is related directly to the time consumed in cleaning fires for the class of engines in service, condition of fires, kind of cleaning done and the extra time which engines stand idle on the pits waiting to be moved as determined by practical operating conditions. Real ash pit design requires that such matters should be definitely determined from observations of local conditions. With such information lacking, it may be assumed for average conditions that to clean one locomotive fire will require thirty minutes' work on the part of two men and that about fifteen minutes' idle time will occur before the engine is moved. In other words, assuming two men at work, an engine will be forty-five minutes on the ash pit. The usual range of time for the mere work of cleaning fires with two men, not counting idle time, is from twelve to forty-five minutes, and this time very rarely is less than six or more than seventy-five minutes.

The size of the ash pit force which will actually be used with any design can perhaps be estimated best from the usual practice throughout the country, which seems remarkably uniform. Reports submitted by various railroads indicate that at terminals handling from 60 to 300 engines per day, the force is quite uniformly at the rate of one 8-hour man to every five or six engines; at terminals handling 30 to 60 engines per day, the rate is one man to every four or five engines, and for terminals of less than 30 engines, a minimum force of six men is generally employed. It should be recognized that any reduction of ash pit forces below that number needed to take care of the rush hour conditions will render unsatisfactory the service obtained from any type of ash pit regardless of its physical capacity or how well it may have been designed to handle peak loads.

Dependability of Operation

The second essential requirement of all ash pits has been termed—"Dependability of Operation." This refers particularly to freedom from interrupted service due to labor supply or labor troubles, to break-down of mechanical equipment, to delays from other terminal and yard work and to non-use of pit while undergoing repairs. This also refers to reliability of operation under extreme weather conditions, periods of traffic congestion as affecting supply of empty ash cars and switching of loaded ash cars, temporary breaks in power supply, etc. All successful operation of engine terminals and all efficient handling of train movements depends vitally upon known and dependable performance at the ash pit. It may not be so important at some terminals that engines be handled quickly over the ash pit, as it is that such handling of engines should be dependable and at a known rate. The greater the number of engines handled, the more serious are the results of breakdowns. Many officials seem to minimize the ill effects of breakdowns and seem willing to assume the slight risks of failure of mechanical equipment because of confidence in a well organized and efficient organization. It cannot be denied, however, that any breakdown in rush hours is apt to completely upset the efficiency of the entire terminal. There is, however, great latitude for difference of opinion and judgment about the relative importance of many features of construction and arrangements which are required mainly to increase dependability of operation and this difference of opinion, to a large extent, accounts for the common use of so many different kinds of ash pits.

It must be admitted, however, that other considerations being equal, the following features are favorable to dependability of operation and should be incorporated in ash pit designs or operations, so far as may be consistent:

(1) Work should be done mechanically, so far as possible, to reduce the force employed to a minimum or to make work easy and attractive to labor as an inducement to low wages or steady work. A man shoveling wet cinders in stormy weather is certain to take an easier job at the first opportunity.

(2) Uninterrupted service requires that for each class of labor there shall be substitutes always within reach.

(3) Spare parts of mechanical equipment should be kept on hand and, generally, no mechanical equipment should be used which cannot either be replaced or repaired quickly.

(4) Liberal storage space for ashes should be provided, as it is common knowledge that much of the dissatisfaction with the operation of certain types of ash pits is due to the accumulation of ashes and ash cars. At most terminals the switching of ash cars should not be necessary more than once a day. There is a decided advantage where ashes can be handled directly to a storage pile.

(5) The disposal of ashes should be so arranged as not to actually delay cleaning of locomotive fires and handling of engines over the pit.

Economy of Operation

Economy of ash pit operation is related primarily to the economical operation of the railroad as a whole. Time saved at the ash pit is time available for power in revenue service. Ample and dependable ash pit service under all conditions is the essential economic requirement and not merely that the ash pit costs per engine be the lowest possible. However, the cost per engine is a very important consideration. At a sixty-engine terminal, a saving of 20 cents per engine means a yearly saving of $4,380.00. The real cost per engine should be considered as including operating costs, maintenance, interest on the investment and obsolescence. The life of the investment is often a vital consideration on account of the many changes being made in small and medium size terminals in an effort to meet the constantly growing demands incident to increase of traffic, the use of heavier and new types of power and the more exacting demands of modern railroad operation. With some types of ash pits there is very little salvage value, while with other types from one-third to one-half the investment can be saved if re-arrangement of facilities becomes necessary.

At all terminals the larger part of the cost of operating ash pits is the direct expense of cleaning fires, an item of cost which is largely independent of the type of pit or the means used for ash disposal. At small terminals the force of fire cleaners cannot be reduced below a certain minimum number, often between six and eight men per day, and even these men are idle a great part of the time unless other classes of work are required of them. At such terminals there is not much economy in mechanical equipment, unless, even with the use of such equipment, there is plenty of other work to keep the ash pit force busy and this work is of such a nature that it can be dropped at any time and thus not affect the dependability of either ash pit operations or other essential terminal work. At the larger terminals, where ash pit facilities are reasonably permanent, the actual daily cost of removing the ashes to cars is apt to be a fixed daily cost independent of the number of engines handled. Reports seem to indicate that in most cases, crane operators and their helpers are not used so very much on other kinds of work and that, generally, the ash pit is charged with a day's expense for this force. As a result, deep and shallow water pits will show a cost of removing ashes into cars of 5c to 20c, dependent merely upon the number of engines handled. Some roads get economical results by using these men on other work, which is economical, provided such work does not affect the character of service given by the ash pit. Where mechanical coaling plants have ample storage and hoisting capacity, it is often possible for the same force to handle both the coaling plant and the ash disposal without delay to either class of work and without affecting dependability of service of either the coal chute or the ash pit.

Fixed charges per engine for many ash-handling plants vary from 10 to 30 cents. No very reliable figure can be given, as many plants in service do not have sufficient capacity, while other plants have 50 to 100 per cent excess capacity for existing needs, which would correspondingly increase fixed charges to be divided by the number of engines actually handled. In fact, any attempt to compare advantages and disadvantages of various types of pits on the basis of real total cost per engine handled will only lead to conclusions under a certain set of assumed conditions which may or may not represent actual operating conditions. As a general statement, it may be said that under conditions similar to those of 1920, if the labor payroll cost of cleaning fires and handling ashes into cars exceeds $1.00 per engine, then careful investigation should be made to establish the reason for the high cost. Many such costs are between 70 and 80 cents and some much lower. Reduced wages and increased efficiency should proportionately reduce these figures.

Recommendations Regarding Common Types of Ash Pits and Methods of Ash Disposal

(1) All ash pits should have water pipes conveniently arranged for quenching fire and for attachments of hand hose for use of fire cleaners on each side of each engine.

(2) In estimating ash storage, and deciding the required size of skips, hoppers, etc., the average amount of ashes per engine and the maximum amount for any one engine should be determined from a knowledge of local conditions. With such information lacking, the average amount of ashes per engine should be assumed as not less than two yards and preferably two and one-half yards; and in the design of skips and hoppers the maximum amount of ashes from any one engine should be assumed as not less than two and one-half yards and preferably three yards.

(3) Length of pits handling two engines per track should be from 1½ to 1¾ times the length of a single engine, and length of pits handling three engines per track should be between 2½ and 2¾ times the length of a single engine. The length of engine selected should suitably reflect existing and probable future operating needs.

(4) Cleaning of locomotive fires on line of road is often an operating necessity, though it involves some risk to traffic unless ashes receive proper attention. Such fire cleaning should be prohibited, except at designated locations between fixed limits where proper attention can be given to the removal of the ashes. Such locations should be suitably distant from switches and highway grade crossings.

(5) Where only a few engines are handled daily, many small ash pit arrangements may be suitable, but consideration should be given to the use of a shallow pit constructed of non-combustible material and located between the rails.

(6) The depressed track pit, with ashes removed to cars by hand, has given fairly satisfactory service throughout the country for many years at terminals handling from a few up to a hundred or more engines per day. With modern labor conditions and operating requirements, the general use of this type of pit is not recommended, though under favorable labor conditions, and under conditions not favorable to the use of machinery, such pits will probably continue in satisfactory service at some terminals.

Where such pits are to be used, it is recommended that they generally embody the following features:

(a) Concrete should be of a dense and rich mixture, with preferably slag or trap rock used for the aggregate.

(b) For safety and economical maintenance, both rails should be supported on cast iron or cast steel pedestals even though a continuous curtain wall be used under one rail.

(c) Pavement should be of vitrified or fire brick on a concrete base.

(d) The distance from base of rail to pavement should be not less than three, nor over four feet.

(e) To prevent the washing of ashes down onto the depressed track, the retaining wall should project slightly above the paving, with drain holes through it.

(f) Vertical distance from top of rail of depressed track to edge of shoveling platform should be not less than four feet six inches and usually not over five feet six inches, based upon easy shoveling into cars of ordinary height and possible shoveling into cars nearly eleven feet high.

(4) The Robertson and N. & W. type ash-handling plants are essentially similar and in comparison with other types of ash pits, are recommended more particularly for terminals handling from 10 to 60 engines per day. For larger terminals up to those handling 100 engines per day, this type may compete in economy with other ash pits; however, as the number of units employed increases, a large area is required for a proper track layout and dependability of operation is much less than with shallow and deep water pits, so far as abnormal conditions are concerned.

The Robertson conveyor is installed in single and double units, the double unit being required to receive the ashes from locomotives having two to three hoppers. Each track opening is about five feet long and each skip holds about 1½ cubic yards. The single unit should be used only in exceptional cases, where it is known that its ash capacity is equal to the local demand.

The N. & W. type conveyor is usually installed as a single unit. Its hopper is 8 feet long and the skip has a capacity of about three cubic yards. To care for some engines, a double unit would be needed.

With these two types of pits, the track layout should be carefully checked for engine and ash car movements. Ash-handling units in the same engine track should be spaced, at least, the length of three ash cars, to allow the placing of two cars to the unit and the dropping down of a loaded car without interference with the cars placed at the next unit. Ash handling units on separate engine tracks preferably should discharge into the same ash car, provided the track connections are such that all ash cars do not have to be switched simultaneously. All overhead and side construction should allow unrestricted use of all tracks by any engine or car.

(5) Deep water pits are recommended for use where 60 or more engines are handled daily, provided the engine terminal layout is so fixed that the ash pit investment may be considered reasonably permanent, and provided that the climate is not so cold that great trouble is apt to be experienced in unloading frozen ash cars. For terminals handling 60 to 100 engines per day, such pits are probably slightly more expensive in real cost per engine than some other types; however, this greater cost is often or may be justified by the greater dependability of operation. For terminals handling over 100 engines daily the cost per engine is probably as low as for any other type, and the dependability greater.

It is recommended that such pits embody the following features or ideas:

(a) Ashes should be removed to cars with clam shell buckets operated by locomotive, gantry or overhead cranes. At double pits, if the use of a locomotive crane is required for more than two or three hours per day, then dependability of operation will begin to be affected and overhead crane should be installed.

(b) Engine and ash car tracks should be spaced far enough from adjacent tracks to afford suitable clearances for the future construction of an overhead crane runway.

(c) The smaller layouts should provide at least two engine tracks, or consist of two separate, single engine pits in the same track, with suitable crossovers to a running track and with an independent ash car track, this latter arrangement being recommended only where local conditions make the usual two-engine pit undesirable.

(d) The larger layouts should provide at least two engine tracks and one or more independent ash car track, all spanned or served by a crane. Where the extra cost involved can be justified, complete non-interference between the work of loading ashes and the cleaning and handling of engines can be obtained by locating the ash track between the engine tracks.

(e) Distance center to center of engine tracks over pits should be not less than eighteen feet, and correspondingly increased if sidewalks are provided. Depth of pit and the slope of the side walls should be such that ashes will slide freely to the middle, where they can readily be reached by the bucket. Ashes will not flow freely on a slope less than one to one.

(f) Such rails as do not bear on side walls, should be supported on pedestals spaced relatively close together in order to permit the use of shallow beams and reduce maintenance cost in the replacement of these beams. Spare bearing beams should be kept in stock at all times so that prompt replacement of defective beams can be made. The use of bare beams probably will be safer and cheaper than to attempt to protect such beams from rust and warping from the heat.

(g) The bottom of the pit should be protected with old rails or otherwise to guard against blows and scraping action of the clam shell bucket.

(h) Special attention should be given to the use of catch basins and other arrangements to keep cinders from filling up drain pipes.

(i) Consideration should be given to safeguards against accidents resulting from men falling into the pit. Good protection is afforded by inner sidewalks with railings. These can be installed only when so provided in the original design, and even then at a decided increase in cost on account of increased track centers and depth of pit for equal ash storage.

(6) Shallow water pits are recommended for use under about the same conditions as are deep water pits. In all cases, the ashes should be handled by overhead crane. Comparing these two types, it may be said for equal lengths, the shallow water pit will be cheaper construction, and therefore more economical in fixed charges. If, however, on account of the reduced ash storage the length of the pits be increased, then the advantage of economy may be partly or wholly lost. With the larger terminals, the ash storage is usually such that the ash removal requires five to eight hours' work of a craneman and usually a helper. At smaller terminals, two to four hours' work is all that is required, and the same force may also work hoisting coal. To a certain extent, the shallow ash pit is less dependable in operation than the deep water pit, because its ash storage is less, but practically, the difference is very slight. Such pits should embody the following features:

(a) Engine tracks and ash car tracks should alternate in either a three or five track unit under one crane.

(b) Pits should be as wide between the rails as they can be constructed. The side walls and bottom of the pit should be protected against rubbing by clam shell bucket, which should be extra long to obtain good capacity. Height of pit walls should not be less than four feet or more than four feet six inches.

(c) Between tracks a water shedding pavement should be provided so sloped as to drain to the pits.

Ash-handling plants may be developed in the future, which will be more economical and satisfactory than those above recommended, but most of the many other arrangements now in use fail to show any particular advantages other than adaptation to either local conditions or operating needs. The type which has a transverse chamber under the tracks is well adapted to handle ashes from engines on line of road or in terminals where four or more tracks are used under a combined coaling and ash-handling plant. In the latter case, some of the tracks may be used inbound or outbound, according to requirements.

In conclusion, it should be recognized that unsatisfactory service from common types of ash pits will generally reflect either insufficient or poorly supervised operating forces or else a plant which is overworked or inadequate in its physical capacity to properly meet the terminal requirements. It is of vital interest to railroad managements to see that ash-pit layouts are carefully and liberally designed for local needs and to see that proper terminal operation and train dispatching, as a whole, are not handicapped by insufficient ash-pit force to properly meet the rush-hour demands as they change from day to day and year to year.

Exhibit "A"
Cost of Cleaning Fires and Loading Ashes Into Cars
Robertson and N. & W. Conveyors

Railroad	Location	Type of Ash Pit	Test Period: Date	Test Period: Length (Days)	Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
1	Massachusetts	Robertson Conveyor	Jan. 1 to 28, 1921	28	690	25
2	Georgia	Robertson Conveyor	Nov. 29, 1920, to Jan. 23, 1921	56	1355	24
3	Wisconsin	Robertson Conveyor	Jan. 24 to Feb. 7, 1921	14	1289	92
3	Iowa	Robertson Conveyor	Jan. 24 to Feb. 7, 1921	14	523	37
4	Illinois	Robertson Conveyor	Nov. 1 to 28, 1920	28	998	36

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars

ROBERTSON AND N. & W. CONVEYORS—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
20"x26" to 23"x32"	Consol	77	$692.16	$1.00	3 8-hr. shifts—Total	
22"x26"	Pacific	14			3 firecleaners at 53c per hr	
21"x28"	6 Wh. Sw	4			3 helpers at 50c per hr	
23"x32"	8 Wh. Sw	4				
21½"x32" : 34"x32"	Mallet	1				
20"x28" to 23"x28"	Pacific	23	$1469.44	$1.08	3 8-hr. shifts—Total	
27"x30"	Mikado	21			8 men at 41c per hr	
20"x28" and 22"x30"	Consol	18				
18"x24" to 21"x26"	10 Wh	14				
24"x32" : 38"x32"	Mallet	12				
	Misc	12				
....	Consol	41	$1157.52	$0.898	156 man hrs. per day at 53c per hr	Engines classed as to grate area:
	6 Wh. Sw	33				12 to 19 sq. ft..... 4%
	Prairie	7				26 to 27 sq. ft.....32%
	10 Wh	7				30 to 36 sq. ft..... 5%
	Mikado	5				44 to 53 sq. ft.....55%
	Mallet	4				71 to 73 sq. ft..... 4%
	8 Wh. Sw	1				
	Misc	2				
....	Consol	....	$384.72	$0.73	56 man hrs. per day at 49c per hr	
	Mikado					
	10 Wh	....				
	8 Wh	....				
	Pacific	....				
	Prairie	....				
	6 Wh. Sw	....				
20"x28"	Consol	38	$941.84	$0.944	3 8-hr. shifts—Total	
19"x26"	Mogul	16			8 men at 48½c per hr	
21"x26"	6 Wh. Sw	13				
27"x30"	Mikado	12				
25"x28"	Pacific	10				
18"x24"	8 Wh	8				
19½"x26"	10 Wh	3				

Exhibit "A"
Cost of Cleaning Fires and Loading Ashes Into Cars—Continued
Robertson and N. & W. Conveyors—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
4	Illinois	Robertson Conveyor	Nov. 1 to 28, 1920	28	756	27
5	Kentucky	Robertson Conveyor	Jan. 1 to 28, 1921	28	750	27
6	Pennsylvania	Robertson Conveyor	Nov. 15 to Dec. 12, 1920	28	1016	37
7	Virginia	Robertson Conveyor	Jan. to Feb., 1921	28	1190	43
7	S. Carolina	Robertson Conveyor	Jan. 12 to Feb. 8, 1921	28	852	30
8	Georgia	N. & W.	Sept. 1 to 28, 1920	28	987	35

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Robertson and N. & W. Conveyors—Continued

Class of Engines Handled: Cylinder	Type	Per Cent of Total	Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
27"x30"	Mikado		$865.76	$1.15	2 11-hr. shifts—Total 5 men at 49.5c per hr	
21"x26"	6 Wh. Sw					
20"x28"	Consol					
21"x24" to 21"x30"	Consol	56	$161.16	$0.215	3 8-hr. shifts—Total 6 men 3 men at 49.5c, 3 at 47c	Cinder pitmen work 75% of total time on other terminal work.
23"x30" to 24" x30"	Consol	3				
16"x24" to 18"x24"	8 Wh	20				
18"x24" to 20"x26"	10 Wh	19				
	Misc	2				
25"x28" to 27"x30"	Pacific	28	$1260.27	$1.24	3 8-hr. shifts—Total 11 men at 53c per hr	
22½"x28" to 27"x30"	Mikado	25				
20"x24" and 21"x28"	10 Wh	15				
20"x24" and 21"x30"	Consol	10				
20"x24"	6 Wh. Sw	10				
21"x28"	8 Wh. Sw	7				
20"x24"	8 Wh	3				
20"x26"	Atlantic	2				
27"x32"	Santa Fe	28	$551.04	$0.463	3 8-hr. shifts—Total 6 men at 41c per hr	
27"x30" and 29"x28"	Mountain	26				
22"x28" and 24½"x28"	Pacific	25				
20"x26" to 22"x30"	Consol	12				
20"x26"	6 Wh. Sw	5				
26"x30"	Mikado	4				
25"x28"	8 Wh. Sw	25	$447.95	$0.526	6 men—rates 39½c, 41c, 45¾c and 47¾c.	Part of time of day men charged to other work.
27"x30"	Mikado	22				
21"x28" and 22"x30"	Consol	20				
22"x28"	Pacific	12				
20"x26"	6 Wh. Sw	12				
27"x30": 20"x24"	Mallet	9				
20"x26" and 21"x28"	Consol	44	$352.80	$0.357	3 8-hr. shifts—Total 9 men at 42c per hr	
23"x28" and 24"x30"	Consol	20				
23"x28" and 24"x28"	Pacific	14				
25"x30"	Mikado	10				
18"x26"	6 Wh. Sw	6				
19"x26"	8 Wh. Sw	5				
23"x32"	12 Wh	1				

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

ROBERTSON AND N. & W. CONVEYORS—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
9	Virginia	N. & W.	Dec. 1 to 28, 1920	28	2108	75
9	W. Virginia	N. & W.	Dec., 1920	28	1814	65
9	Ohio	N. & W.	Dec., 1920	28	1823	65
DEEP WATER PITS (ASHES REMOVED WITH CRANES)						
1	Massachusetts	Deepwater (Gantry Crane)	Dec. 3 to 30, 1920	28	3286	117
3	Iowa	Deepwater (Locomotive Crane)	Jan. 24 to Feb. 7, 1921	14	367	26

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Robertson and N. & W. Conveyors—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
22"x32" : 35"x32" 25"x32" : 39"x32"	Mallet	28	$2462.88	$1.17	3 8-hr. shifts—Total 18 men at 53c per hr. 3 men at 48½c per hr.	Given number of engines does not include those having fires re-cleaned on leaving engine house.
21"x30"	Consol	26				
28"x30" and 29"x28"	Mikado	23				
21"x30" and 24"x30"	12 Wh.	12				
20"x28" and 22"x28"	Pacific	8				
20"x28"	10 Wh.	3				
22"x32" : 35"x32" 25"x32" : 39"x32"	Mallet	37	$1424.84	$0.79	3 8-hr. shifts—Total 12 men at 53c per hr.	Given number of engines does not include those having fires re-cleaned on leaving engine house.
21"x30"	12 Wh.	24				
21"x30"	Consol	17				
21½"x28" and 20"x28"	Prairie	13				
	Misc.	9				
22"x32" : 35"x32" 24½"x32" : 39"x32"	Mallet	33	$794.62	$0.436	2 12-hr. shifts—Total 4 men at 53c for 8 hrs. and time and one-half for 4 hrs.	Given number of engines does not include those having fires re-cleaned on leaving engine house.
21"x30"	Consol	26				
20"x28" and 22½"x28"	Pacific	15				
21"x30"	12 Wh.	14				
19½"x28" and 20"x24"	10 Wh.	6				
24½"x30" : 39"x30"	Mallet (0-8-8-0)	6				
Deep Water Pits (Ashes Removed with Cranes)						
22"x26"	Pacific	37	$2690.46	$0 82	2 12-hr. shifts—Total 12 firecleaners at 51½c 1 craneman at 81c—1 8-hr. shift 6 days per week	
20"x26" to 23"x32"	Consol	23				
25"x32"	Mikado	13				
21"x28"	6 Wh. Sw.	9				
23½"x30"	8 Wh. Sw.	8				
21½"x32" : 34"x32"	Mallet	4				
27"x32"	Sante Fe	3				
	Misc.	3				
18"x26" and 22"x28"	10 Wh.	42	$377.48	$1.03	45.5 man hrs. per day at 53c per hr. 1 craneman at 82c—1⅓ hrs. per day.	Engines classed as to grate area: 12 to 19 sq. ft. ...... 10% 22 to 26 sq. ft. ...... 19% 34 to 35 sq. ft. ...... 5% 47 to 49 sq. ft. 66%
24"x30"	Consol	21				
18"x24" and 19"x26"	6 Wh. Sw.	20				
26"x30"	Mikado	12				
25"x28"	Pacific	4				
18"x24"	8 Wh.	1				

Exhibit "A"
Cost of Cleaning Fires and Loading Ashes Into Cars—Continued
Deep Water Pits (Ashes Removed with Cranes)

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
3	Iowa	Deep Water (Locomotive Crane)	Jan. 24 to Feb. 7, 1921	14	301	22
10	New Jersey	Deep Water (Overhead Traveling Crane)				275
11	New York	Deep Water (Overhead Traveling Crane)	Nov. 25 to Dec. 22, 1920	28	2380	85
12	Pennsylvania	Deep Water (Gantry Crane)	Dec., 1920	28	3309	118
13	New Jersey	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	1236	44

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
26"x30"	Mikado	40	$388.72	$1.29	51.5 man hrs. per day at 53c per hr.	Engines classed as to grate area:
19"x26" to 21"x30"	10 Wh.	14			1 man at 41c and 1 craneman at 82c per hr. working part time	17 to 18 sq. ft. 11%
23"x30" to 27"x28"	Consol	14				30 to 34.16 sq. ft. . . 5%
15"x25"x28"	Atlantic	14				44 to 48.8 sq. ft. . . .84%
21"x28" and 23"x28"	Pacific	14				
18"x24"	8 Wh.	4				
19"x26" to 23"x28"	10 Wh.	35	$173.50 per day	$0.631	3 8-hr. shifts—Total	Chief engineer advises that submitted data shows average condition better than would be shown for any 28-day period.
18"x24" to 22"x26"	6 Wh. Sw.	21			42 firecleaners at 60c per hr.	
18"x26"	Prairie	12			1 craneman 8 hrs. per day at 81c per hr.	
22"x26"	Atlantic	10				
19"x24"	8 Wh.	9				
24"x30"	8 Wh. Sw.	2				
	Misc.	11				
23"x30" to 27"x32"	Consol	54	$2900.48	$1.22	17 firecleaners on piece work at $1.09 per engine	
20"x24" to 21½"x30"	Consol	39			1 8-hr. shift for craneman at 81c and 1 lab. at 48½c per hr.	
33"x32" : 20½"x32"	Mallet (Yard)	1				
	Misc.	6				
25"x28"	Pacific	22	$2668.00	$0.806	14 men—10-hr. shifts. Piece work rates: 53c for Mogul and Sw. Eng. plus 10c per hr. 63.6c for Consol., Pac. and Mikado Eng. plus 10c per hr. Average hourly earnings about 71c.	
21"x26"	Consol	20				
19"x24"	6 Wh. Sw.	19				
21"x32"	12 Wh.	11				
21"x26"	Mogul	11				
19½"x24" and 20"x26"	8 Wh.	7				
22"x28"	8 Wh. Sw.	6				
	Misc.	4				
22"x30" and 25"x28"	8 Wh. Sw.	27	$1362.37	$1.10	3 8-hr. shifts—Total	
28"x32"	Mikado	24			10 men at 53c per hr.	
19"x24" to 22"x32"	Consol	19			1 craneman at 80c per hr.	
19"x24" and 20"x26"	6 Wh. Sw.	15				
27"x28"	Pacific	13				
21"x26"	10 Wh.	2				

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
13	New York	Deep Water	Jan. 1 to 28, 1921	28	2155	77
13	New York	Deep Water	Jan. 1 to 28, 1921	28	1943	69
13	Pennsylvania	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	817	29
13	New York	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	23	1372	49
13	New York	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	1398	50

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
22"x32" to 28"x32" 19"x24" to 22"x32" 22½"x26" and 27"x28" 18"x26" and 22½"x26" 17"x24" 21"x28"	Consol Consol Pacific Atlantic 6 Wh. Sw Decapod Misc	45 11 30 3 3 2 6	$1297.25	$0.602	3 8-hr. shifts—Total 9 men on piece work basis of 55c per engine 1 craneman 4 hrs. per day at 82c 2 lab. each ¾ hr. per day at 48c	
22"x30" to 24"x32" 19"x24" to 21"x30" 22½"x26" and 25"x28" 28"x32" 18"x26" 25"x28"	Consol Consol Pacific Mikado Atlantic 8 Wh. Sw Misc	40 12 22 9 8 3 6	$1972.90	$1.02	2 shifts. Total 8 men on piece work at 84c per engine cleaned 1 craneman at 80c 1 lab. at 48½c	Piece work earnings average 59c per hr.
19"x24" to 22"x30" 28"x32"	Consol Mikado	59 41	$1246.20	$1.52	3 8-hr. shifts—Total 8 firecleaners at 53c per hr 3 laborers at 48½c per hr 1 craneman 2 hrs. per day at 82c per hr	
22"x30" and 22"x32" 19"x24" to 21"x28" 18"x26" 28"x32" 19"x24" and 20"x26" 22½"x26" 25"x28" 21"x26"	Consol Consol Atlantic Mikado 6 Wh. Sw Pacific 8 Wh. Sw 10 Wh. Sw	33 14 16 13 13 6 4 1	$1212.60	$0.884	2 shifts—Total 8 men on piece work at 82c per engine cleaned 1 craneman at 80c per hr 1 laborer at 48½c per hr	Craneman and laborer's time on cinder pit work averages about 2½ hrs. per day. Piece work earnings average 64c per hr.
21"x28" to 24"x32" 22½"x26" and 25"x28" 27"x32" and 28"x32" 19"x24" 18"x26"	Consol Pacific Mikado 8 Wh. Sw Atlantic	48 29 17 5 1	$1535.48	$1.098	2 shifts—Total 8 men on piece work basis of 90c per engine cleaned 1 craneman at 80c per hr 3 laborers at 48½c per hr	Craneman and laborer's time on cinder pit work averages about 3½ hrs. per day. Piece work earnings average 53c per hr.

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
13	Ohio	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	1531	55
13	Indiana	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	791	28
13	Indiana	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	1315	18
4	Tennessee	Deep Water (Locomotive Crane)	Nov. 1 to 28, 1920	28	1401	50
4	Illinois	Deep Water (Locomotive Crane)	Nov. 1 to 28, 1920	28	1669	60
4	Tennessee	Deep Water (Locomotive Crane)	Nov. 1 to 28, 1920	28	1756	63

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
30"x32 to 31"x32"	Sante Fe	47	$2062.14	$1.347	3 8-hr. shifts—Total	
28"x32"	Mikado	19			9 men on piece work basis of 87c per engine cleaned	
22½"x26" to 27"x28"	Pacific	14			1 craneman at 80c, 3 hrs. per day	
22"x30" and 22"x32"	Consol	14			3 laborers at 48½c per hr	
25"x28"	8 Wh. Sw	3			Hourly rates govern pay of ashpitmen.	
19"x24" and 20"x26"	6 Wh. Sw	3				
21"x28" to 24"x32"	Consol	94	$424.16	$0.536	3 8-hr. shifts—Total	
20"x26"	6 Wh. Sw	4			6 men at 53c per hr	
	Misc	2			1 craneman at 80c per hr	
21"x28" to 22"x30"	Consol	78	$1652.65	$1.23	3 8-hr. shifts—Total	
22½"x26"	Pacific	16			12 men at 53c per hr	
19"x28"	Atlantic	3			1 craneman at 80c per hr	
19"x24" and 20"x26"	6 Wh. Sw	2				
	Misc	1				
20"x28"	Consol	35	$1167.06	$0.833	3 8-hr. shifts—Total	Craneman employed only part time in removing ashes.
27"x30"	Mikado	34			11 men at 46½c per hr	
21"x26"	6 Wh. Sw	30			2 cranemen at 80c per hr	
29"x32"	Sante Fe	1				
27"x30"	Mikado	44	$1881.79	$1.13	3 8-hr. shifts—Total	Craneman employed only part time in removing ashes.
25"x28"	Pacific	18			12 men at 53c per hr	
21"x26"	6 Wh. Sw	18			1 craneman at 80c per hr	
20"x28"	Consol	6				
21"x28"	Atlantic	6				
19½"x26"	10 Wh. Sw	3				
18"x24"	8 Wh. Sw	3				
19"x26"	Mogul	2				
21"x28"	6 Wh. Sw	64	$1211.67	$0.69	3 8-hr. shifts—Total	Craneman employed only part time in removing ashes.
25"x28"	Pacific	19			12 men at 46½c per hr	
19½"x26"	10 Wh. Sw	13			1 craneman at 80c per hr	
20"x28"	Consol	2				
19"x26"	Mogul	2				

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
4	Illinois	Deep Water (Locomotive Crane)	Nov. 1 to 28, 1920	28	1711	61
5	Alabama	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	1498	54
5	Kentucky	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	2223	79
6	Pennsylvania	Deep Water (Gantry Crane)	Nov. 15 to Dec. 12, 1920	28	2397	86
8	Tennessee	Deep Water (Locomotive Crane)	Dec. 23, 1920, to Jan. 19, 1921.	28	835	30
8	Tennessee	Deep Water (Locomotive Crane)	Jan. 1 to 28, 1921	28	1058	38

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
27"x30" 21"x26" 20"x28" 25"x28"	Mikado 6 Wh. Sw Consol Pacific Misc	54 23 7 7 9	$1980.32	$1.16	3 8-hr. shifts—Total 12 men at 51½c per hr 2 cranemen at 85c per hr	Craneman employed only part time in removing ashes.
21"x24" to 23½"x30" 19"x26" to 20"x26" 17"x24" to 18½"x24" 19"x24" to 20"x26"	Consol 6 Wh. Sw 8 Wh. Sw 10 Wh. Sw Misc	69 14 6 5 6	$1240.64	$0.828	3 8-hr. shifts—Total 6 laborers at 45½c per hr 6 laborers at 40½c per hr 1 craneman at 80c per hr	Craneman employed on other work about ⅔ of time.
21"x26" to 24"x30" 20½"x28" to 25"x28" 18"x24" and 19"x26" 18"x24" and 20"x24"	Consol Pacific 6 Wh. Sw Mogul Misc	52 26 9 8 5	$2078.58	$0.935	3 8-hr. shifts—Total 19 men at 50¼c per hr 1 craneman at 80c per hr	
22½"x28" to 27"x30" 20"x24" to 22"x28" 19"x24" to 21"x28" 27"x28" and 29"x32"	Mikado Consol 10 Wh. Sw Pacific Misc	48 18 15 10 9	$3139.78	$1.31	3 8-hr. shifts—Total 16 men at 53c per hr 1 craneman at 81c per hr 7 firecleaners on piece work basis at 60c per engine cleaned and 30c for recleaning	Ash pit laborers are employed part of time on other work.
25"x30" and 26"x30" 22"x26" 25"x28" 21"x28" and 22"x24" 27"x30"	Mikado 10 Wh. Sw Pacific Consol Mtn Misc	41 23 14 12 8 2	$477.66	$0.572	3 8-hr. shifts—Total 9 men at 41c per hr 1 craneman at 80c per hr	Only 19 hrs. time of craneman required in 28 days to clean pit and load, ashpitmen employed other work 45% of time. All fires killed at this terminal.
25"x30" and 26"x30" 23"x25" and 25"x28" 20"x26" to 24"x30" 18"x24" and 19"x26" 23"x32" 27"x30" 19"x24"	Mikado Pacific Consol 6 Wh. Sw 12 Wh. Mtn 8 Wh.	30 23 15 13 11 6 2	$626.66	$0.592	3 8-hr. shifts—Total 6 men at 41c per hr 1 craneman at 80c per hr 1 helper at 41c per hr	Only 20 hrs. time of craneman required in 28 days to clean pit and load ashes.

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
14	Ohio	Deep Water (Gantry Crane)	Jan. 1 to 28, 1921	28	1895	68
14	Ohio	Deep Water (Gantry Crane)	Jan., 1921	28	1672	60
14	Pennsylvania	Deep Water (Locomotive Crane)	Jan. 4 to 31, 1921	28	1834	66
7	Georgia	Deep Water (Locomotive Crane)	Jan., Feb., 1921	28	1181	32
7	Kentucky	Deep Water (Locomotive Crane)	Jan. 12 to Feb. 8, 1921	28	1524	54
15	New York	Deep Water (Gantry Crane)	Dec. 31, 1920, to Jan. 27, 1921	28	1377	49

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
20"x24" to 26"x28" 24"x26" to 26"x26" 30"x32"	Consol Pacific Santa Fe Misc	46 34 10 10	$2619.04	$1.38	3 8-hr. shifts—Total 9 hostlers at 70c per hr 9 laborers at 53c per hr 1 craneman at 80c per hr	
20"x24" to 26"x28" 30"x32" 19"x26" to 20"x24"	Consol Santa Fe 6 Wh. Sw Misc	64 26 8 2	$1882.66	$1.13	3 8-hr. shifts—Total 8 hostlers at 70c per hr 3 helpers at 53c per hr 2 cranemen at 81c per hr	Reported expense includes some other classes of work.
22"x28" to 25"x28" 27"x30" 30½"x32"	Consol Mikado Santa Fe Misc	79 15 5 1	$1301.80	$0.71	3 8-hr. shifts—Total 9 hostlers on piece work at 32c per engine cleaned for Santa Fe and Mikado. 28.9c for all other engines 6 ashmen at 53c per hr 1 craneman 2 days per week at 80c per hr	
21"x28" to 24"x30" 17"x24" and 20"x26" 27"x30" 28"x32"	Consol 6 Wh. Sw Mikado Santa Fe	50 29 18 3	$2142.93	$1.81	20 men per day at 51.3c per hr	Locomotive crane also used to coal engines.
20"x24" and 22"x30" 19"x26" 27"x30" 22"x28" and 24"x28" 27"x28" and 27"x30" 18"x24"	Consol 10 Wh Mikado Pacific Mtn 6 Wh. Sw	45 18 16 11 7 3	$1296.96	$0.85	3 8-hr. shifts—Total 12 men at 48¾c per hr	
....	....	....	$1510.99	$1.10	Ashpitmen 93.8 man hrs. per day at 50¼c per hr 1 fuel laborer 11 hrs. per day at 50¼c per hr 1 craneman at 61½c per hr 1 fuel foreman at 81c per hr	Craneman worked only 24 hrs. in 28-day period on ash pits. Fuel foreman worked only 28 hrs. in 28-day period on ash pits.

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
15	Massachusetts	Deep Water (Gantry Crane)	Dec. 31, 1920, to Jan. 27, 1921	28	2585	92
15	Massachusetts	Deep Water (Gantry Crane)	Dec. 31, 1920, to Jan. 27, 1921	28	1106	40
15	New Hampshire	Deep Water (Gantry Crane)	Dec. 31, 1920, to Jan. 27, 1921	28	1076	38
Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)						
1	Massachusetts	Depressed Track	Dec. 3 to 30, 1920	28	2776	99
1	New York	Depressed Track	Dec. 3 to 30, 1920	28	1456	52

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Deep Water Pits (Ashes Removed with Cranes)—Continued

Class of Engines Handled: Cylinder	Type	Per Cent of Total	Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
....	....	....	$3210.63	$1.24	Ashpitmen 48.2 man hrs. per day at 50¼c per hr. 1 gantry engineer at 81c per hr. 1 grab engineer at 77¾c per hr. 1 grab fireman at 51⅞c per hr. 1 laborer at 50¼c per hr. Firecleaners 45c per engine plus 12c per hr. Firecleaner's helper 39c per engine plus 12c per hr.	Gantry engineer and laborer work only 51 hrs. in 28-day period on ash pits. Grab engineer and fireman work only 20 hrs. in 28-day period on ash pits.
....	....	....	$645.30	$0.583	4 firecleaners at 50¼c per hr. 1 craneman at 81c per hr. 1 laborer at 49½c per hr. 1 pocketman at 54c per hr. 1 pocketman at 51c per hr.	Pocketmen work only 48 and 64 hrs. respectively in 28-day period on ash pits. Craneman and laborer worked 120 hrs. each on ash pits during 28-day period.
....	....	....	$726.01	$0.674	Firecleaners 34 man hrs. per day at 50¾c per hr. 1 craneman 40 hrs. at 81c per hr. 1 ashpitman 12 hrs. per day at 46½c per hr.	

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Cylinder	Type	Per Cent of Total	Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
22"x26" 21"x28" 21½"x32" : 34"x32" 25"x32" 20"x26" to 23"x32" 18"x24" 23½"x30"	Pacific 6 Wh. Sw. Mallet Mikado Consol 8 Wh. 8 Wh. Sw. Misc.	29 15 11 11 10 8 7 9	$1855.60	$0.67	3 8-hr. shifts—Total 10 men on piece work at 60c per engine cleaned 1 craneman at 80c	Ashes removed with gasoline operated locomotive crane.
21"x30" and 23"x32" 22"x26" 21"x28" 27"x32"	Consol Pacific 6 Wh. Sw. Santa Fe Misc.	45 31 9 6 9	$1447.00	$1.03	2 12-hr. shifts with extra men working 5, 6 and 10 hrs. per day—Total 7 men at 50¾c per hr. to 51½c per hr. 2 men 5 to 6 hrs. per day at 80c per hr.	Ashes removed by locomotive crane.

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)

Railroad	Location	Type of Ash Pit	Test Period: Date	Test Period: Length (Days)	Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
15	Massachusetts	Depressed Track	Dec. 31, 1920, to Jan. 27, 1921	28	1290	46
15	New Hampshire	Depressed Track	Dec. 31, 1920, to Jan. 27, 1921	28	407	15
3	Illinois	Depressed Track	Jan. 24 to Feb. 7, 1921	14	1009	72
3	Iowa	Depressed Track	Jan. 24 to Feb. 7, 1921	14	369	27
3	Wisconsin	Depressed Track	Jan. 24 to Feb. 7, 1921	14	824	59
3	Wisconsin	Depressed Track	Jan. 24 to Feb. 7, 1921	14	682	49

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
....	....	....	$1120.00	$0.868	Firecleaners 32 man hrs. at 51½c per hr. Ashpitmen 48 man hrs. per day at 49c per hr........	
....	....	....	$168.84	$0.414	Ashpitman 12 man hrs. per day at 50¼c per hr........	
26"x30" and 27"x32"........ 22"x28" to 24"x30"........ 23"x28" and 25"x28"........ 21"x28"........ 14"x26"........ 13"x22"x26" and 15"x25"x28"........	Mikado........ Consol........ Pacific........ Mogul........ 6 Wh. Sw........ Atlantic........ Misc........	25 18 15 14 12 7 9	$1590.00	$1.57	215 man hrs. per day at 53c per hr.....	Engines classed as to grate area: 17 to 26 sq. ft.....16% 30 to 35 sq. ft..... 6% 44 to 49 sq. ft.....56% 53 to 71 sq. ft.....22%
18"x24" and 19"x26"........ 13"x22"x26" and 15"x25"x28"........ 15"x25"x28" and 15"x25"x30"........ 18"x24" and 24"x30"........ 21"x28"........ 24"x30"........	6 Wh. Sw........ Atlantic........ 10 Wh........ 10 Wh........ Prairie........ Consol........ Misc........	31 17 16 15 10 7 4	$474.81	$1.29	64 man hrs. per day at 53c per hr.....	
	Pacific........ Mikado........ Atlantic........ 10 Wh........ Misc........	48 25 20 3 4	$875.82	$1.06	110.6 man hrs. per day at 53c per hr.. 3.4 man hrs. per day at 83¾c per day. 2.4 man hrs. per day at 43c per hr....	Ashes removed by locomotive crane. Engines classed as to grate area: 30 to 36 sq. ft..... 8% 44 to 49 sq. ft.....81% 71 sq. ft.........11%
23"x28" and 25"x28"........ 21"x28"........ 26"x30" and 27"x32"........ 23"x30"........ 18"x24" to 21"x30"........ "x26"........	Pacific........ Mogul........ Mikado........ Consol........ 10 Wh........ 6 Wh. Sw........ Misc........	39 15 10 15 8 7 6	$1067.24	$1.56	150.6 man hrs. per day at 53c per hr..	Ashes removed by locomotive crane. Engines classed as to grate area: 17.2 to 18.8 sq. ft. 7% 25 to 35 sq. ft.....13% 44 to 48.8 sq. ft...71% 70.8 sq. ft........ 9%

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
10	New Jersey........	Depressed Track..	....	....	....	60
10	New Jersey........	Depressed Track..	....	....	....	10
11	Pennsylvania......	Depressed Track..	Nov. 18 to Dec. 15, 1920.....	28	2536	91
11	New York........	Depressed Track..	Nov. 20 to Dec. 17, 1920.....	28	1930	69
13	Pennsylvania......	Depressed Track..	Jan. 1 to 28, 1921............	28	656	23
13	Pennsylvania......	Depressed Track..	Jan. 1 to 28, 1921............	28	1605	57
5	Alabama..........	Depressed Track..	Jan. 1 to 28, 1921............	28	995	36

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
20"x32" 20"x24" 18"x24" and 20"x26" 21"x26"	12 Wh. Consol 6 Wh. Sw. 10 Wh.	43 33 14 10	$65.50 per day	$1.09	12 firecleaners 3 ashpitmen	Chief engineer advises that submitted data shows average conditions better than would be shown for any 28-day period.
20"x24" 18"x24" 21"x26" 20"x32"	Consol 8 Wh. 10 Wh. 12 Wh.	30 30 20 20	$11.75 per day	$1.18	5 firecleaners 1 ashpitman	Chief engineer advises that submitted data shows average conditions better than would be shown for any 28-day period. Force employed 50% of time on other work.
23"x30" to 27"x32" 21"x26" to 22"x30" 26"x28" : 41"x28" 19"x24" and 20"x24"	Consol Consol Mallet (pusher) 8 Wh. Misc.	38 23 23 9 7	$6257.50	$2.47	3 8-hr. shifts—Total 14 firecleaners on piece work at $1.10 per engine cleaned Wheelcovermen at 50¾c per hr. 18 ashpitmen at 50¾c per hr.	
18"x24" to 20½"x24" 20"x26" to 21½"x30" 23"x30" to 27"x32" 17"x22" and 19"x24" 24"x28" 20¾"x26" to 22"x26" 26"x28" : 41"x28"	8 Wh. Consol Consol 6 Wh. Sw. Pacific 10 Wh. Mallet (yard)	25 23 7 21 15 8 1	$2727.53	$1.41	3 8-hr. shifts—Total 11 firecleaners on piece work at 75c per engine cleaned 9 ashpitmen at 53c per hr.	
19"x24" to 22"x30" 28"x32" 21"x26"	Consol Mikado 10 Wh.	54 37 9	$1015.00	$1.55	3 8-hr shifts—Total 9 men at 53c per hr.	
27"x32" and 28"x32" 20"x24" to 22"x32" 30"x32" and 31"x32" 22½"x26" to 27"x28" 19"x24" and 20"x26" 17"x24" and 20"x26"	Mikado Consol Santa Fe Pacific 10 Wh. 8 Wh. Misc.	23 23 21 19 6 4 4	$2133.02	$1.33	2 12-hr. shifts—Total 8 men on piece work at 85c per engine cleaned and day rate of 52c per hr. 2 clam shell engineers each 7 hours per day at 82c per hr. 2 laborers at 48½c per hr.	Cost includes $24.96 for thawing ash pans. Ashes removed by clam shell which may be operated between or outside of track rails.
22½"x28" to 24"x30" 20"x26" to 22"x28" 20"x24" to 21"x30" 19"x26" and 20"x24" 18"x24" 27"x30" 20"x24"	Consol Pacific Consol 6 Wh. Sw. 8 Wh. Mikado Mogul	29 27 19 9 8 7 1	$1332.16	$1.34	3 8-hr. shifts—Total 14 men at 44¾c per hr. 2 cranemen at 80c per hr.	Ashes removed by hand and by locomotive crane.

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
5	Kentucky	Depressed Track	Jan. 1 to 28, 1921	28	2070	74
16	Michigan	Depressed Track	Sept. and Oct., 1920	60	1069	18
16	Ohio	Depressed Track	Sept. and Oct., 1920	60	1403	23
16	Michigan	Depressed Track	Sept. and Oct., 1920	60	2012	33
16	Michigan	Depressed Track	Sept. and Oct., 1920	60	1557	26
16	Michigan	Depressed Track	Sept and Oct., 1920	60	6225	104
16	Michigan	Depressed Track	Sept. and Oct., 1920	60	5740	96
16	Ontario	Depressed Track	Sept. and Oct., 1920	60	3567	59

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
26"x30" to 28"x30"	Mikado	25	$2459.52	$1 19	3 8-hr. shifts—Total	
21"x26" to 21"x30"	Consol	20			8 men at 45¾c per hr	
22"x30" to 24"x30"	Consol	17				
23½"x30" and 25"x28"	8 Wh. Sw	17				
20"x28" to 25"x28"	Pacific	16				
	Misc	5				
19"x26" and 21"x28"	6 Wh. Sw	83	$481.20	$0.45	8-hr. shifts—Total	
23½"x30"	8 Wh. Sw	13			2 men per day at 52c per hr	
19"x24"	10 Wh	4				
18"x24" and 21"x28"	6 Wh. Sw	54	$631.20	$0.45	3 8-hr. shifts—Total	
26"x30" and 27"x30"	Mikado	34			3 men at 52c per hr	
23½"x30" and 23"x35"x21"	8 Wh. Sw	10				
	Misc	2				
23"x35"x32" and 23"x35"x34"	Consol	30	$905.40	$0.45	3 8-hr. shifts—Total	
23½"x30" and 25"x28"	8 Wh. Sw	27			4 men at 53c per hr	
26"x30" and 27"x30"	Pacific	18				
21"x28"	6 Wh. Sw	13				
19"x24" to 20"x26"	10 Wh	7				
	Misc	5				
18"x24" to 21"x28"	6 Wh. Sw	78	$700.80	$0.45	3 8-hr. shifts—Total	
23"x32"	Consol	13			3 men at 52c per hr	
23½"x30" and 25"x28"	8 Wh. Sw	7				
27"x30"	Mikado	2				
21"x26" and 23½"x26"	Pacific	24	$5911.45	$0.95	3 8-hr. shifts—Total	
26"x30" and 27"x30"	Mikado	21			17 men at 52.6c per hr	
19"x24" to 25"x28"	8 Wh. Sw	19				
18"x24" to 21"x28"	6 Wh. Sw	17				
19"x24"	Mogul	5				
20½"x28"	Prairie	4				
26"x28" : 40"x28"	Mallet	1				
	Misc	9				
19"x26" and 21"x28"	6 Wh. Sw	22	$4667.97	$0.813	3 8-hr. shifts—Total	Cost includes some expense of hostler helpers for other work than cleaning fires.
23"x32" and 23"x35"x32"	Consol	21			10 hostler helpers at 63c per hr	
23½"x30" and 25"x28"	8 Wh. Sw	21			10 pitmen at 52c per hr	
27"x30"	Mikado	20				
19"x24" and 20"x28"	10 Wh	12				
	Misc	4				
	Consol	.0	$2341.29	$0.656	3 8-hr. shifts—Total	
	Pacific	38			10 men at 49½c per hr	
	6 Wh. Sw	11				
	10 Wh	6				
	Misc	5				

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Railroad	Location	Type of Ash-Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
16	Michigan	Depressed Track	Oct. 1 to 28, 1920	28	1806	65
7	Tennessee	Depressed Track	Jan. 12 to Feb. 9, 1921	28	1864	67
7	Alabama	Depressed Track	Jan. and Feb., 1921	28	1070	38
14	Indiana	Depressed Track	Jan. 1 to 28, 1921	28	2037	73
18	Indiana	Depressed Track	July 1 to 31, 1921	31	1856	60
18	Ohio	Depressed Track	July 1 to 31, 1921	31	2048	66
18	Ohio	Depressed Track	July 1 to 31, 1921	31	1238	40

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Depressed Track Pits (Ashes Removed by Shoveling Into Cars, Except as Noted Otherwise)—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
	Mikado 6 Wh. Sw Consol Pacific 10 Wh Atlantic	43 13 12 12 12 8	$2046.24	$1.13	3 8-hr. shifts—Total 18 men at 50¾c per hr	
20"x24" to 22"x30" 22"x28" and 24"x28" 19"x24" and 20"x26" 28"x32" 27"x30" 21"x28"	Consol Pacific 6 Wh. Sw Santa Fe Mikado Mogul Misc	34 16 13 12 12 6 7	$3158.40	$1.69	3 8-hr. shifts—Total 30 men at 47c per hr	
22"x30" to 24"x30" 27"x30" 20"x26" 22"x28" and 24"x28" 21"x28" 27"x28"	Consol Mikado 6 Wh. Sw Pacific 10 Wh Mtn	35 22 17 14 7 5	$1411.20	$1.32	15 men at 42c per hr	
20"x24" to 26"x28" 20½"x26" to 27"x28" 18"x24" to 20½"x26" 20"x24" and 22"x28"	Consol Atlantic 8 Wh 6 Wh. Sw Misc	54 22 10 6 4	$1775.98	$0.872	3 8-hr. shifts—Total 14 men at 52c per hr 1 craneman at 84c per hr 1 fireman at 62c per hr	Reported cost covers 54 hours' service of craneman and fireman and a charge of $1.04 per hr. for use of crane.
....	6 Wh. Sw Pacific Mikado Consol Atlantic 8 Wh. Sw	30 23 20 12 10 5	$928.00	$0.50	3 8-hr. shifts—Total 6 men (see remarks)	Rate 39½c per hr. Hourly piece work earnings 62c.
....	Mikado Pacific Consol Atlantic 8 Wh. Sw 6 Wh. Sw	38 30 13 9 6 4	$1331.60	$0.65	3 8-hr. shifts—Total 9 men (see remarks)	Rate 39½c per hr. Hourly piece work earnings 65.7c.
....	....	....	$619.00	$0.50	3 8-hr. shifts—Total 5 men (see remarks)	Rate 39½c per hr. Hourly piece work earnings 50c.

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Shallow Water Pits (Built Between Rails—Ashes Removed with Cranes)

Railroad	Location	Type of Ash Pit	Test Period: Date	Test Period: Length (Days)	Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
14	Pennsylvania	Shallow Water (Electric traveling overhead crane)	Jan. 4 to 31, 1921	28	3328	119
14	Pennsylvania	Shallow Water (Overhead crane)	Jan. 12 to Feb. 8, 1921	28	1279	46
14	Pennsylvania	Shallow Water (Electric traveling overhead crane)	Jan. 4 to 31, 1921	28	1792	64
14	Pennsylvania	Shallow Water (Overhead traveling crane)	Jan. 4 to 31, 1921	28	4333	155
7	North Carolina	Shallow Water (Overhead traveling crane)	Jan. 14 to Feb. 10, 1921	28	2064	74
7	Alabama	Shallow Water (Electric traveling overhead crane)	Jan. and Feb., 1921	28	1409	50

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Shallow Water Pits (Built Between Rails—Ashes Removed with Cranes)

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
20"x24" to 22"x28" 23"x28" to 26"x28" 27"x30" 30½"x32" 25"x30" : 40"x28"	Consol Consol Mikado Decapod Mallet Misc	43 20 18 11 3 5	$2322.27	$0.698	3 8-hr. shifts—Total 24 hostlers at 70c per hr 24 ashmen at 53c per hr Craneman	Only portion of time chargeable to ash pit work.
22"x28" and 23"x28" 30½"x32" 27"x30" 27"x28"	Consol Decapod Mikado Pacific	81 10 8 1	$945.36	$0.74	3 8-hr. shifts—Total 12 hostlers on piece work 6 ashmen at 53c per hr	Hostlers receive piece work rate of 28.9c for Consol. engines, 32c for Decapod, Mikado and Pacific engines. In addition they receive $1.346 for 8 hours' work for all operations: i. e., for cleaning fires, filling sand boxes, moving and coaling engines, etc. 20% of this is assumed as chargeable to cleaning fires in addition to piece work rates.
20½"x26" and 23½"x26" 24"x26" and 27"x28" 22"x24" 18½"x26"	Atlantic Pacific 6 Wh. Sw 8 Wh	38 23 23 16	$2301.16	$1.28	3 8-hr. shifts—Total 10 hostlers at 70c per hr 8 ashpitmen at 53c per hr 1 craneman at 81c per hr	
24"x26" and 27"x28" 20"x24" and 22"x24" 22"x26" 22"x28" to 26"x28" 20"x28" 18½"x26" 23"x28"	Pacific 6 Wh. Sw Atlantic Consol Mogul 8 Wh 10 Wh	38 22 18 6 6 5 5	$2782.29	$0.64	3 8-hr. shifts—Total 23 hostlers on piece work 11 ashmen at 53c per hr	
27"x28" to 28"x32" 22"x24" and 24"x28" 17"x24" to 20"x26" 20"x24" to 22"x30" 26"x30" and 27"x30"	Santa Fe Pacific 6 Wh. Sw Consol Mikado Misc	27 25 22 16 6 4	$2159.36	$1.046	13 men at 63c per hr 1 craneman at 81c per hr 1 foreman at 64c per hr	Cost given includes a small amount of work other than cinder pit work.
24"x28" 27"x30" 22"x30" 20"x28" and 21"x28" 20"x24" to 21"x28" 22"x28" and 24"x28"	8 Wh. Sw Mikado Consol 6 Wh. Sw 10 Wh Pacific	20 19 16 16 15 14	$1942.76	$1.38	13 men at 44½c per hr	

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

MISCELLANEOUS PITS

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
5	Tennessee........	Shallow Pit between Rails. Ashes removed by loco. crane and by hand	Jan. 1 to 28, 1921............	28	1965	70
5	Alabama..........	Shallow Pit between Rails. Ashes removed by hand...	Jan. 1 to 28, 1921............	28	720	26
8	Tennessee........	Open Pit between Rails. Ashes removed by hand......	Jan. 1 to 28, 1921............	28	99	4
14	Indiana...........	Long Pits in 5 tracks discharging into bucket conveyor in transverse chamber beneath..........................	Jan. 1 to 28, 1921............	28	2797	100
14	Illinois...........	3 tracks with hoppers discharging into car operated in transverse chamber beneath..........................	Jan. 1 to 28, 1921............	....	1562	56
14	Ohio.............	4 Pits between rails and 1 wide Pit. Ashes removed by overhead crane.......................................	Jan. 1 to 28, 1921............	28	863	31
14	Pennsylvania......	Pit between rails filled with buckets on wheels which are unloaded by moving them to a stationary hoist........	Jan. 4 to 31, 1921............	28	1661	56

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Miscellaneous Pits—Continued

Class of Engines Handled			Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
Cylinder	Type	Per Cent of Total				
20"x24" to 21"x30"	Consol	23	$1734.49	$0.882	3 8-hr. shifts—Total	Craneman is employed only part of time handling cinders.
20½"x28" to 25"x28"	Pacific	22			9 men at 43½c per hr	
18"x24" to 20"x26"	6 Wh. Sw	22			9 men at 42c per hr	
19"x24" and 20"x24"	Mogul	15			1 craneman at 80c per hr	
18"x24" to 20"x26"	10 Wh	10			1 helper at 42c per hr	
17"x24" and 18"x24"	8 Wh	8				
20"x28" and 20½"x28"	Pacific	44	$1580.86	$2.22	3 8-hr. shifts—Total	
21"x28"	Consol	28			14 ashpitmen at 44c per hr	
21"x24"	6 Wh. frt	25				
	Misc	3				
18"x24"	10 Wh	49	$53.31	$0.54	3 8-hr. shifts—Total	Only a portion of these men's time chargeable to ash pit work.
20"x24" and 20"x26"	Consol	45			3 men at 41c per hr	
16"x24"	8 Wh	6				
20"x24" to 26"x28"	Consol	52	$2140.35	$.765	3 8-hr. shifts—Total	
24"x26"	Pacific	21			14 firecleaners and pitmen at 53c per hr	
22½"x26"	Atlantic	9			4 hostlers at 70c per hr	
19"x26" to 20"x28"	10 Wh	7				
20"x26" to 21½"x28"	Mogul	5				
	Misc	6				
22"x28" and 26"x28"	Consol	79	$1763.40	$1.13	3 8-hr. shifts—Total	
19"x26" and 22"x28"	6 Wh. Sw	20			17 men at 53c per hr	
30"x32"	Santa Fe	1				
20"x24" to 26"x28"	Consol	42	$1869.68	$2.17	3 8-hr. shifts—Total	
24"x26" to 27"x28"	Pacific	17			7 hostlers at 70c por hr	
20½"x26" to 22½"x26"	Atlantic	15			8 ashpitmen at 53c per hr	
30"x32"	Sante Fe	13				
19"x24" and 20"x28"	10 Wh	5				
19"x26"	6 Wh. Sw	5				
18"x24"	8 Wh	3				
22"x28" to 25"x28"	Consol	61	$1173.64	$0.71	3 8-hr. shifts—Total	Part of time chargeable to other work.
27"x30"	Mikado	33			12 men at 70c per hr	
	Misc	6				

Exhibit "A"

Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Miscellaneous Pits—Continued

Railroad	Location	Type of Ash Pit	Test Period		Number of Engines Handled Over Pit in Test Period	Number Engines Per Day
			Date	Length (Days)		
14	Ohio	Track Hoppers discharging ashes into cars moving in transverse underground tunnel with hoisting arrangement overloading track.	Jan. 10 to Feb. 8, 1921	30	4277	142
17	Pennsylvania	Pit between rails holding 6 buckets of 2 yds. capacity with elevated bin and hoisting arrangements for storage of ashes and their subsequent discharge into cars on loading track	Dec. 1 to 28, 1920	28	290	10
17	Pennsylvania	Pit between rails holding 6 buckets of 2 yds. capacity with elevated bin and hoisting arrangements for storage of ashes and their subsequent discharge into cars on loading track	Dec. 1 to 28, 1920	28	520	20
17	Pennsylvania	Pit between rails holding 6 buckets of 2 yds. capacity with elevated bin and hoisting arrangements for storage of ashes and their subsequent discharge into cars on loading track	Dec. 1 to 28, 1920	28	2369	85
		Track Hoppers discharge ashes into cars moving in transverse underground tunnel with hoisting arrangement over loading track	Nov., 1920	30	1279	46

Exhibit "A"

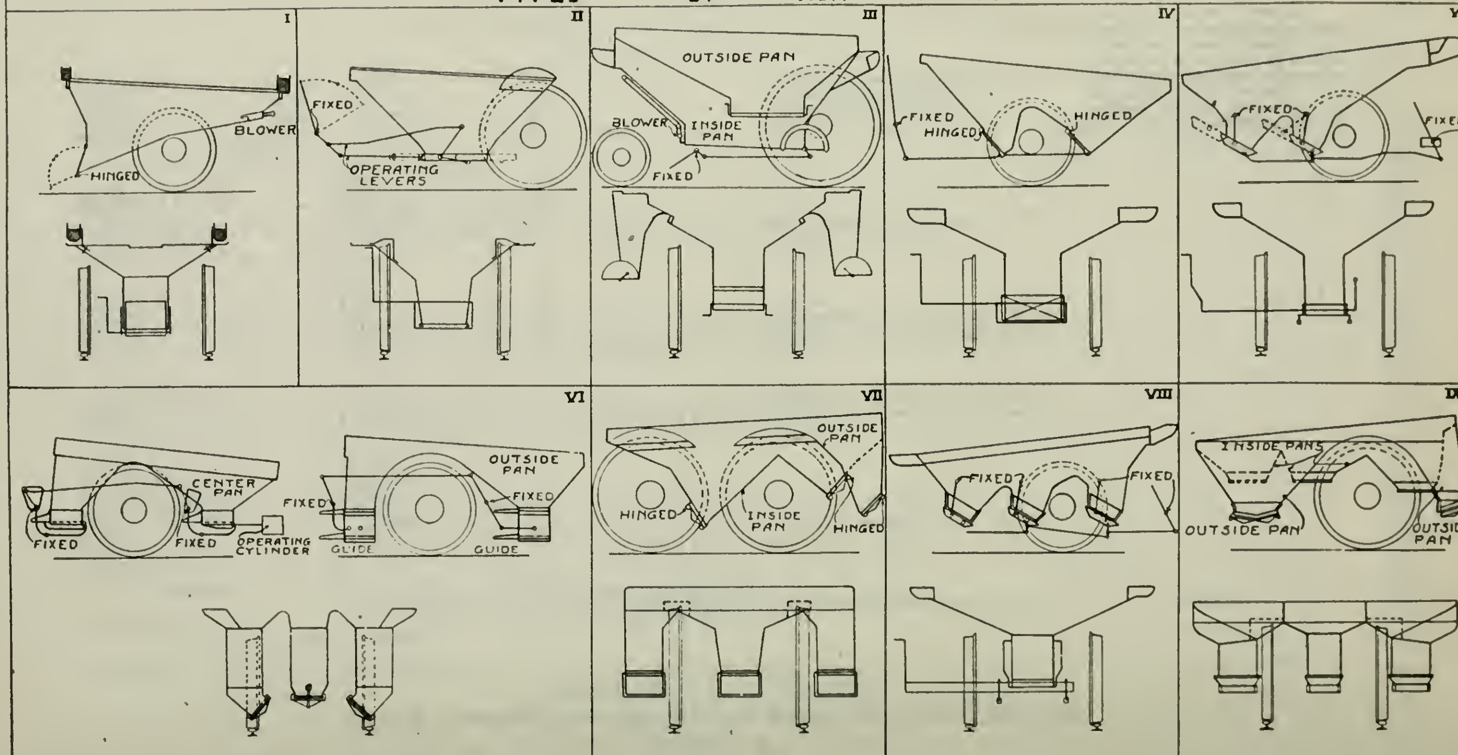
Cost of Cleaning Fires and Loading Ashes Into Cars—Continued

Miscellaneous Pits—Continued

Class of Engines Handled: Cylinder	Type	Per Cent of Total	Total Pay Roll Labor Cost	Cost Per Engine	Force Employed and Rates of Pay	Remarks
22"x28" to 26"x28" 30"x32" 24"x26" to 27"x28" 20½"x26" to 22½"x26" 19"x26" and 22"x24" 27"x30"	Consol Sante Fe Pacific Atlantic 6 Wh. Sw Mikado Misc	42 19 16 13 4 3 3	$4197.60	$0.98	3 8-hr. shifts—Total 33 men at 53c per hr	
20"x26" 27"x30" and 27"x32"	6 Wh. Sw Consol	98 2	$815.00	$2.81	3 hostlers 8 hrs. per day at 70c per hr. 4 ashpitmen 9 hrs. per day at 53c per hr.	
20"x26" 22"x26" 19½"x26" 23½"x26"	6 Wh. Sw 10 Wh. 8 Wh. Pacific Misc	49 30 9 4 8	$1133.65	$2.18	3 hostlers 8 hrs. per day at 70c per hr. 6 ashpitmen 8 hrs. per day at 53c per hr	
20"x26" to 22½"x30" 27"x30" and 27"x32" 20"x26" 20"x26" and 23½"x26"	Consol Mikado 6 Wh. Sw Pacific Misc	29 28 26 12 5	$1624.99	$1.95	12 hostlers at 70c per hr 18 ashpitmen at 53c per hr	
Tractive Power 27"x30" 66390 27"x32" 60000 26"x30" 54600 22½"x30" 51638	Grate Area 60 sq. ft 70.8 sq. ft 66.7 sq. ft 51.6 sq. ft Misc	 38 38 11 6 7	$1241.61	$0.97	3 8-hr. shifts—Total 23 lab. at 59½c per hr 1 foremen at 70c per hr 2 ass't foremen at 68c per hr	This is a special installation for cleaning fires of engines of main line freight trains en route. It is stated that the plant is designed to dispose of ashes of 12 locomotives per hour. Results here shown for test period show plant working at about ⅓ capacity.

Exhibit B

TYPES OF ASH PANS.



Appendix B

ENGINE HOUSE AND POWER PLANTS AND SHOP EXTENSION, COLLABORATING WITH DIVISION V—MECHANICAL

Engine Houses

GEO. W. BURPEE, *Chairman;*
E. A. HARRISON,
L. P. KIMBALL,
J. W. PFAU,
Sub-Committee.

Your Committee on Construction of Engine Houses, as one of its items under Subject (3), was appointed on October 2, 1920, with instructions to study and report on the Construction of Engine Houses in co-operation with a Committee of Division V—Mechanical, of the American Railway Association, which has had the same subject under consideration.

On December 15, 1920, the full membership of the Sub-Committee met at the American Railway Association offices in Chicago with the corresponding Committee of the Mechanical Division of the A. R. A., to discuss the subject matter of the Final Report of the latter Committee.

The conclusions reached at this meeting, as a result of information obtained by the Mechanical Division, together with information subsequently secured from this Sub-Committee's Questionnaire, form the basis of the report presented herewith.

On the 27th of January, 1921, a Questionnaire covering the principal features of the Design and Construction of Engine Houses was submitted to approximately fifty members of the Association to elicit information relating more particularly to present tendencies in design as exemplified in the most modern houses. Replies were received from the representatives of forty-two different railroads, covering all sections of the United States and Canada, and embracing all varieties of climate.

The Committee wishes to express its appreciation of the promptness and thoroughness with which the information was furnished.

Following is the Questionnaire:

(1) Please submit two prints each of plans and sections of what you consider the best round houses on your road. In cases where you have modern round houses with wood frame, reinforced concrete or steel frame, it is suggested that you submit prints of each. The prints should show length of turntable, distance from edge of turntable to inner edge of house, width of stall at inner edge, track angle or number of stalls in the full circle, all dimensions of the house proper such as clear height at door, height at rear side, clearance at doors, etc., and length, width, depth, wall thickness, etc., of engine pits.

(2) For what class or classes of power is this round house or round houses to which you refer used?

(3) How many engines are cared for in the round house per day? How many during the busy period? What is the duration of the busy period?

(4) What type of floors have you found most satisfactory in a round house? Upon how many years' service of the type of floor in question is your opinion based? Have you found any type of floor particularly unsatisfactory?

(5) What type of roof have you found most satisfactory? Upon how many years' service of the type of roof in question is your opinion based? Have you found any particular types of roof unsatisfactory? It is understood that the roof here refers to the roof proper, such as wood, reinforced concrete, combination reinforced concrete and hollow tile, gypsum block, etc., and not to the waterproofing.

(6) What type of doors and windows do you consider most satisfactory, i. e., swinging, folding, rolling lift doors, wood or steel sash, etc.?

(7) What type of lighting have you used; general illumination by flood lights, individual lights widely distributed, or a combination, and what degree of intensity of light have you found most satisfactory?

(8) What degree of heat have you found to be satisfactory in the round house during ordinary cold weather and what type of heating system do you consider most efficient?

(9) If direct radiation, what location do you consider most effective for radiators or coils?

(10) If indirect radiation, is air drawn from outside or re-circulated? How many changes of air per hour? Are ducts located underground or overhead? If underground, at inner or outer edge of round house? What do you consider the most effective location for the outlets, at the posts or in the pits?

(11) With what type of smoke jack have you had most success? What is the length parallel to track? Size of outlet through roof?

(12) Where your round houses are provided with traveling cranes what is the capacity of such cranes? Where jib cranes are used please show their location and capacity. Do you use tractors to handle parts from the jib cranes? Where monorails are used, please show location and capacity. What is your opinion in regard to relative effectiveness of these various devices for handling the heavier parts of the locomotives?

(13) How many drop pits are provided? Please submit prints showing details of the drop pit.

(14) Are your round houses equipped with unwheeling hoists, and, if so, have you found the unwheeling hoist economical for this purpose in comparison with the drop pit?

(15) In the case of round houses where no back shop is provided, what space and what tools do you provide for machine shop work for maintaining running repairs?

(16) To what legal requirements are you obligated to conform which affect side clearances, overhead clearances, sanitary facilities, heating or other features?

(17) Have you any special agreements with the workman affecting in any way the design of the round house or the facilities provided?

Replies were received from representatives of these railroads:

Atchison, Topeka & Santa Fe Railway.
Baltimore & Ohio Railroad.
Boston and Maine Railroad.
Canadian National Railways.
Canadian Pacific Railway.
Central of Georgia Railroad.
Central Railroad of New Jersey.
Chesapeake & Ohio Railroad.
Chicago & Western Indiana Railroad.
Chicago & Northwestern Railway.
Chicago, Burlington & Quincy Railroad.
Chicago Great Western Railway.
Chicago, Rock Island & Pacific Railway.

Chicago, Milwaukee & St. Paul Railway.
Delaware & Hudson Company.
Delaware, Lackawanna & Western Railroad.
Denver & Rio Grande Railway.
Duluth, Missabe & Northern Railroad.
Elgin, Joliet & Eastern Railway.
El Paso & Southwestern System.
Grand Trunk Railway.
Great Northern Railway.
Illinois Central Railroad.
Lake Erie & Western Railroad.
Louisville & Nashville Railroad.
Michigan Central Railroad.
Minneapolis, St. Paul & Sault Ste. Marie Railway.
Missouri, Kansas & Texas Railway.
Nashville, Chattanooga & St. Louis Railway.
Toledo & Ohio Central Railroad (New York Central Lines).
New York Central Railroad.
New York, New Haven & Hartford Railroad.
Norfolk & Western Railway.
Northern Pacific Railway.
Pennsylvania System.
Pere Marquette Railroad.
Philadelphia & Reading Railway.
Pittsburgh & Lake Erie Railroad.
St. Louis-San Francisco Railway.
Southern Pacific Company.
Southern Railway.
Union Pacific Railroad.

The information obtained has been classified and tabulated and is presented in the following exhibits:

(C)—Diagrams of engine house cross-sections.

(D)—Tabulation of General Dimensions and Descriptions.

Previous Reports to the Association on Design of Engine Houses

The subject of the design and construction of Engine Houses has been considered at several periods in the past by the Committee on Buildings and your Committee has carefully studied all previous reports with the idea of bringing up to date the information contained in past "Proceedings."

The first treatment of this subject is found in Volume 6, 1905, and the only subsequent reports in Volumes 7, 9 and 10, 1906, 1908 and 1909, respectively. The subject matter in the current edition of the Manual is based on these previous investigations. Therefore the desirability seems evident of presenting to the Association such information as will show the changes in engine house design during the last twelve years.

Your Committee does not feel that the development of a standard engine house adapted to all conditions on all roads is practicable, but that each situation must be analyzed and such a house constructed as will satisfy most economically the special requirements. It has endeavored, however, to set forth the general considerations of design and layout and to present in a convenient form such information as to the various types, details of design, and materials of construction, as will be of use to members of the Association.

General Principles of Design

Before proceeding further, your Committee wishes to make clear the use and meaning of certain expressions. The term engine house is used throughout instead of round house. The terms inner circle and outer circle are used in referring to the engine house of circular shape instead of the ambiguous terms "front" and "rear."

Classification

There are in general two classes of engines houses which on account of the different purposes they serve require different treatment.

1. Engine houses at points where general shops or other shops for classified repairs are located and where other than running repairs are made in such shops.
2. Engine houses intermediate between such points as are described in (1), where the engines are merely housed, inspected and turned, and where a minimum amount of tool equipment is provided for light running repairs.

The assignment of any projected engine house to one of these two general classes is essential before the house is designed.

Limiting Factors of Layout

The limiting factors in the layout of an engine house of the circular type are:

1. The ultimate number of stalls desired.
2. The spacing of columns on the inner circle.
3. The diameter of the turntable.
4. The practicable distance, center to center, of rails of adjacent tracks at the rim of the turntable to permit the proper clearance between adjacent rails, to secure rigid fastenings and to avoid the use of frogs. The elimination of frogs, while not essential, is desirable.
5. The arrangement of tracks within and without the house so that as many stalls as practicable will line up with the main lead tracks.

Ground Plan

Engine houses may be rectangular or circular. Your Committee believes that in general the circular form is preferable and the subject matter of the report refers principally to circular engine houses, but the rectangular houses, as well as circular houses, are shown in the tabulation presented in Exhibit 2. Topographical conditions and restricted property sometimes make this form economical.

Number of Stalls

The number of stalls varies so with local conditions that it is not possible to establish a general relationship between the number of locomotives turned and the number of stalls that might not be misleading. The quality of water, for instance, has a great influence on the time required to clean boilers, and the method of operation, the switching engines handled, etc., make it desirable that the number of stalls be made an individual study for each engine house, and be determined by the Engineering, Operating and Mechanical Departments working in co-operation.

The Committee of the Mechanical Division of the A. R. A. concluded at their meeting on December 15th, 1920, that one turntable was ordinarily sufficient for a 50-stall engine house provided that ample space was provided for in coming and "ready" locomotives to protect the peak demand for power. In locations where many switching engines are handled, it is customary to provide a separate turntable to turn switching engines which do not go into the house.

Turntable

Very few new engine houses are being constructed with a turntable less than 100 feet long. The general range in length is from 85 to 110 feet. Your Committee feels that the present specification in the Manual is satisfactory, "The turntable should be long enough to balance the engine when the tender is empty." Few turntables, except those serving very small houses, are now without tractors, usually operated by electric power.

Length of Engine House Along Center Line of Stall

The length of a modern engine house varies from 80 to 132 feet. The length is determined by the class of power to be cared for. In cases where several classes are handled, it is customary to construct sections of different lengths, the number of stalls of each length being determined by the number of engines of each class to be housed. The conclusion of the Mechanical Division's Committee at the meeting mentioned previously was that the house should be at least twenty (20) feet longer than the longest engine to be housed, in order to allow ten (10) feet for working and trucking space at the outer circle in front of the engine, ten (10) feet at the rear of the engine to provide ample working room with the tender detached and door closed. Your Committee concurs in the conclusion of the Committee of the Mechanical Division.

In determining the length of stall, due consideration must be given to future requirements and provision made for extension in length without disturbing the existing structure.

Height

The height at the *inner* circle wall should be sufficient to allow for the doors and the necessary lintels over the doors, but greater height than this is not necessary. The height at the outer circle wall should be sufficient to allow the locomotive to pass through the outer wall without damaging the roof structure. It is suggested that in order to provide for future lengthening of stalls the height be such that if the stall length be increased by 25 feet or thereabouts and the existing slope of roof maintained, the necessary clearance below the lintel would still be ample to allow the locomotive to pass beneath without damage to the roof structure.

Roof Line

The roof line should be such as to:

1. Provide ample natural light where required.
2. Assist in smoke and gas removal and ventilation.

A

The information submitted to the Committee showed a great variety of types of cross-section. These are shown diagrammatically in Exhibit 1.

Forty-two railroads are shown as using sixteen (16) different types of cross-section. Of wood frame houses, there are 15 types; of reinforced concrete, 5; of steel, 3; and of those adapted to the use of traveling crane, 3.

Details of Design

Frame

By far the greater number of engine houses are constructed with wood frames because a wood frame building is both economical and durable, except in case of fire. When a wood frame is used, the house should be divided by fire walls into sections of not over ten or twelve stalls each, and the framing should be of the character known as "slow burning" as distinguished from "ordinary" frame construction; that is with brick walls and heavy timber posts and girders and heavy roof sheathing.

The desirability of having the engine house fireproof is so evident, and the difference in cost at this time between a fireproof and "slow burning" building is so relatively low, that consideration should, by all means, be given to reinforced concrete or structural steel fireproofed. Reinforced concrete has been subjected to endurance tests now lasting many years and in most cases has proved entirely satisfactory as a framework.

In most cases where structural steel, unprotected, is used, special means are provided for the removal of gases, such as in the Pennsylvania System "Type A" house and in the Pittsburgh & Lake Erie standard engine house. Under ordinary conditions, exposed steel is not recommended, and when steel is used, it should be protected by concrete or tile.

Floor

Information obtained from the questionnaire shows floors in use ranging from creosoted wood blocks to cinders and oiled earth, ranking thus:

	First Choice	*Second Choice*
Concrete	15	3
Wood Block	13	7
Brick	9	5
Mastic	2	3
Cinders	2	.
Limestone Screenings	1	.

Where wood block and brick have been reported unsatisfactory, it appears that the trouble has been settlement due to lack of a substantial base, and to the swelling of wood blocks in a few instances.

The Committee of the Mechanical Division recommends a permanent floor, preferably wood block or brick on a concrete foundation, around the outer circle, where trucking and the great part of the work are done, extending from the outer wall back possibly two bays to include the front part of the engine. It recommends concrete as satisfactory for the remainder of the floor. The slope of the floor should be sufficient to carry water quickly to the drainage system, about ⅛ in. to a foot. Crowning the floor between pits seems to be the ordinary and most satisfactory method of providing floor drainage. In some cases, drainage is provided by depressing the floor between engine pits, collecting the water at catch basins and leading it by drain pipes to the engine pits.

Your Committee concurs in the recommendation of the Committee of the Mechanical Division and considers the ideal floor to be of creosoted wood blocks (12 lb. per cu. ft.) laid direct on a six (6) in. concrete base with a bituminous cushion and filler. Such a floor is easy to truck over, easy to work on, does not ship and does not damage engine parts and tools dropped on it. The amount of creosote specified will render the blocks impervious to water. The block ordinarily used for a machine shop floor is not designed to withstand water and is not so suitable for an engine house floor as the block specified.

Vitrified brick on a concrete foundation makes a satisfactory and durable floor but one not so easy to truck over or work on. Between the pits, concrete is satisfactory and is less expensive than the other types of floor recommended.

Roof

There appears to be a considerable difference of opinion as to what constitutes the most satisfactory roof structure. The results of the questionnaire show the following types in use:

Wood—"slow burning"	18
Wood—"ordinary"	13
Reinforced Concrete and Hollow Tile	6
Reinforced Concrete Slab	5
Gypsum	3

The reinforced concrete slab ordinarily does not appear to be satisfactory on account of the condensation which collects on its under side. In high altitudes, however, where condensation is slight, it has been satisfactory throughout a number of years' service. The use of a hot blast heating system eliminates much of the condensation which occurs with a direct heating system.

In the ordinary range of climates encountered in the United States and Canada, the combination roof of reinforced concrete and hollow tile appears to be the most satisfactory fireproof roof. The hollow tile provides satisfactory insulation and decreases or eliminates the condensation which occurs with a solid slab. Several installations of such roofs, however, which have been in service approximately 8 years have shown a tendency to scale. The bottom surface of both tile and concrete spawls off, leaving the rods exposed. Such instances of deterioration can be overcome by the application of a dense plaster, but this development indicates that although a concrete and hollow tile roof is satisfactory as a fireproof roof, it may not be so durable as a wood roof. On the other hand, the roof on the Baltimore & Ohio engine house at Ivorydale, Ohio, a combination roof of *vitrified* hollow tile and reinforced concrete, installed in 1905, shows no evidence of deterioration after 16 years' service.

The wood roof of slow-burning construction with sheathing two (2) in. or thicker, and heavy purlines spaced at relatively wide intervals, has proved generally to be the most durable and is satisfactory except for its lack of fireproof qualities. The purlines should run radially and not circumferentially so that no pockets will be formed to collected smoke and gases.

Gypsum has not yet been subjected to service sufficiently long to determine its durability.

Your Committee recommends that where a fireproof roof is desired, a combination reinforced concrete and tile roof be used, while if a non-fireproof roof be used, the sheathing be not less than two (2) in. in thickness and be supported on heavy roof timbers of slow-burning construction.

Doors

The information obtained from the questionnaire indicates a marked preponderance of opinion in favor of swinging wood doors. Accordion folding doors show promise, and hardware for this type is now being perfected, but these doors have not been subjected to a sufficient test to permit unqualified recommendation. The chief objection to this type of door is the difficulty of making repairs. Any engine house door is liable to damage by locomotives running through it and ease of making repairs is an important characteristic.

Rolling lift doors have not been generally satisfactory on account of the liability of the operating mechanism to get out of order and the difficulty of repairing damage inflicted by locomotives.

The ranking of various types of doors as indicated by the replies to the questionnaire is as follows:

Wood—Swinging	34
Rolling Lift, Wood Slats	6
Wood—Folding	3
Steel—Swinging	1

The Committee recommends the wood swinging door as satisfactory and easily kept in repair. When the door is glazed, wire glass should be used. Attention of the Association is called to an arrangement in use on the Central Railroad of New Jersey, and possibly on other railroads, in which the doors are not fastened directly to the inner circle columns but to independent auxiliary columns called "knock-out posts." When the door is hit by a locomotive and forced out, the "knock-out post" fails and allows the door to give way without damage to the main frame work of the engine house.

The door opening should be not less than seventeen (17) ft. in height and not less than thirteen (13) ft. in width in the clear.

Windows

Replies to the questionnaire show an almost equal division of opinion between wood and metal sash. The objection is raised to metal sash that it corrodes quickly and that when damaged by locomotives it can not be easily repaired. The experience of other roads has proved that metal sash will last indefinitely when painted each year and that when subjected to damage it can be repaired more readily than wood sash.

Metal sash has the great advantage of providing the greatest ratio of glass area to window opening and simplicity of ventilation by pivoted ventilating sections.

Your Committee recommends:

1. For fireproof construction—metal sash.
2. For non-fireproof construction—either metal or wood, depending on cost of sash.

Lighting

Natural lighting should be furnished by the provision of as great an area of windows as can be obtained without sacrifice of structural stability. Abundance of daylight is the most striking characteristic of the modern industrial building. The steam and smoke which are almost constantly present in an engine house make the conditions severe and the necessity for the maximum amount of natural light greater than in the average industrial building. Skylights have not proved successful and the light should be obtained by windows in the outer circle wall, inner circle doors, clere-storey or monitor windows.

There are two general systems of artificial lighting in use:

1. General illumination with individual lights.
2. Flood lights.

Both systems are supplemented by drop cord light attachments on columns between stalls.

There is little uniformity in the intensity of lighting measured on a foot candle basis on account of the diversity of requirements as to intensity as different parts of the stall, and the great dependence on the drop cord light for the location where intense light is required.

The replies to the questionnaire show a preponderance of opinion in favor of individual lights as follows:

General illumination by individual lights	32
Flood lights	6
Combinations of the two methods	5

This subject was considered by the Mechanical Division's Committee but no conclusions were reached.

A satisfactory arrangement where general illumination is used is to provide 1 200-watt lamp, near the outer circle wall, to light the front end of the engine; 2 100-watt and 1 60-watt lamps at intervals between this 200-watt lamp and the inner circle—a total of 460 watts per stall. In addition, sockets for the attachment of drop cord lights are provided on columns between stalls.

No conduit has been found which would withstand the gases prevalent in an engine house. In the case of a reinforced concrete engine house, the conduit is often embedded in the roof; in other cases, in the floor and every effort is made to keep the lamps and fixtures below the gas level.

The flood lighting system has been used successfully by the Boston & Albany and by the Chicago, Milwaukee & St. Paul. The arrangement used by the latter consists of two floor lights per stall, each with 1 100-watt lamp located on the outer circle wall at a height of 8 ft. above the floor line and a distance of 2 ft. 6 in. each side of the center line of the columns, and one flood light with a 60-watt lamp located on each column on the inner circle. Thus 260 watts are provided for each stall. The lamps, by means of their location, diffuse the light and prevent glare or deep shadows. As they are below the gas line, the maintenance is simple. At the two round houses at the Milwaukee shops, where this system has been in use for two years, the only attention needed is the cleaning of the lenses once a week and renewal of lamps. The time of one man 2 or 3 hours a week only is required in contrast with the continuous services of one man required to keep the old system of individual lights in proper shape.

Your Committee believes that general illumination of 400 to 500 watts per stall should be furnished, with provision for drop cord lamps in addition, and that the development of the flood lighting system as described above warrants the careful consideration of the Association.

Heating

Replies to the questionnaire indicate a range in temperature inside of from 50 deg. to 60 deg. Fahr. during ordinary cold weather.

Small houses are heated economically by the direct system with vacuum return. Houses of 10 stalls or more may be satisfactorily heated by either the direct or indirect system. The preponderance of opinion is in favor of indirect heating by hot air blast.

The returns are as follows:

Indirect	25
Direct	20
Stoves or Salamanders	3

When the direct system is used, as much of the radiation as possible should be placed on the pit walls, supplemented by additional radiation on the outer circle wall, and walls and fire wall. Cast iron radiators are preferable on the walls. Those on the outer circle wall should be concentrated near the columns and out of the path the engine would take if it should run through the outer wall. Either cast iron or pipe coil radiation may be used in the pits. Pit walls should be recessed to receive radiators so as to afford protection to the radiators and prevent damage from falling parts of an engine.

When the indirect system is used, the number of air changes per hour should be from 3 to 4. The size of the house modifies this requirement; a small house requires a greater number of changes than a large house.

The replies to the questionnaire give the following information regarding air changes:

No. of Changes Per Hour	*Cases*
2	3
2½	1
3	4
3½	2
4	5
5	1

The main duct is generally located underground around the outer circle wall because any leakage in this location would raise the temperature where men are working, and higher temperatures are desirable, and also because in this location the loss of heat in passing through the ducts is less than if the ducts were located around the inner circle and exposed to cold air entering through the open doors.

The disadvantage in locating the main duct around the outer circle is that in any extensive lengthening of the stall and engine pits, the reconstruction of at least a portion of this duct is necessary. Replies to the questionnaire show 22 cases where the main duct is located at the outer circle and 4 where it is located at the inner circle.

The intake and distribution system should be so arranged that air may be taken entirely from outside, entirely from inside, or part from the outside and part from the inside of the house. The amount of recirculation permissible depends largely on atmospheric conditions but in extreme cold weather an amount up to 25 per cent. is seldom objectionable especially when frequent opening of doors admits much fresh air.

The outlets should preferably be in the engine pits for the purpose of thawing out engines. These outlets should be provided with dampers to permit shutting off the heat when men are working opposite them. Outlets may be provided at the outer circle wall, as well as in the pits.

The temperature of the air at the outlets should be from 130 to 150 deg. Fahr.

Smoke Jacks

There are three types of smoke jacks in general use and the returns from the questionnaire show the preference for these types as follows:

	First Choice	*Second Choice*
Cast Iron	15	5
Asbestos	15	8
Wood	11	9
Special	2	1

The general opinion seems to be that there is no satisfactory smoke jack. Cast iron, asbestos and wood give equal service. Wood jacks should be constructed so as to resist fire and when so built, appear to be as satisfactory as any other type.

Your Committee recommends a smoke jack with a hood 42 in. to 48 in. in width, at least 10 ft. and preferably 12 ft. long, parallel to the track, with a uniform slope to the flue and a flue opening of at least 7 sq. ft.

Ventilation

Ventilation is obtained by:

1. Movable sash, either pivoted or sliding, particularly sash in the the clere-storey or monitor.
2. Slots, 4 in. to 6 in. in width, between walls and roof directly under the eaves, particularly in the clere-storey or monitor. This depends upon the climatic conditions prevalent at the location of the engine house.
3. Annular space 2 in. wide between the smoke jack and the flue to induce air currents to the flue.
4. Roof ventilators at th high points of the roof.

Eaves and Leaders

Downspouts should be wrought or cast iron and not sheet metal. Gutters should be an integral part of the roof and draining to leaders located preferably inside the house and discharging into the main drainage system which is usually located at the inner end of the engine pits.

Outer Circle Wall

The outer circle wall should be so designed and constructed as to permit of the future lengthening of the stalls. The height to the eaves should be such that if the stall were lengthened, say a distance of 25 ft., the height of the lintels over the windows would still be sufficient to allow a locomotive to pass through without damaging the main framework of the house. The wall below the windows should be constructed of brick or tile or other material easily replaced if damaged by a locomotive. All piping, radiators, etc., should, so far as possible, be kept out of the path an engine would take in passing through the outer wall.

Painting

All exposed iron, steel or other corrosive material should be given a coat of suitable paint at least once a year. Interior surfaces of walls and roof should be given each year a coat of whitewash.

Mechanical Handling

The subject of mechanical handling of the heavier parts of a locomotive was considered by the Committee of the Mechanical Division, but no definite conclusions were reached. The consensus of opinion was that some type was essential but that the particular type to be adopted depended on the class of repairs handled in the house and other similar considerations more or less related to local operating conditions. Both traveling cranes and jib cranes were approved to handle the heavier parts in taking down and assembling locomotives, and the use of tractors or shop mules to transport the parts from the locomotive to the shop.

Information received by your Committee shows that out of 42 roads:

21 use no mechanical devices.
7 use traveling cranes.
8 use jib cranes.
8 use monorails.
5 use tractors.
1 use portable crane.
6 are contemplating the use of traveling cranes.

The type and amount of such equipment to be provided depends entirely on the use to which the house is to be put, and whether certain repairs are to be performed in the house or in the shop.

If the heavy work is to be done such as removal of steam domes, superheaters, etc., a traveling crane of 10 to 15 tons capacity is desirable. For handling wheels from the drop pits and side rods, jib cranes of 2 or 3 tons capacity are sufficient. Jib cranes may be provided at the columns next to the outer circle to serve the front ends of locomotives, and at the columns nearest to drop pits to handle the side rods, other parts, etc. It is well in the design of the house to provide structurally for the installation of such jib cranes even though they may be omitted when the house is built.

Monorails have been used with greater or less success to handle the upper works of locomotives.

Portable cranes of 1½ or 2 tons capacity are useful in removing side rods, etc.

Tractors are being used most successfully to transport parts from the locomotives to the back shop, or to the tools where the machine work is done.

The provision of some such facilities in engine houses where much work is done seems essential. The type to be used is dependent on the operation of the house and its selection should be a matter of joint action by the Mechanical and Engineering Departments.

Engine Pits

The information on engine pits obtained by your Committee is tabulated in Exhibit 2. The Mechanical Division's Committee concluded that the following characteristics of the engine pits were desirable:

Distance from inner face of outer wall to inner face of pit wall	13 ft.
Distance from inner circle columns to pit	10 ft.
Clear width of pit	4 ft.
Clear depth, minimum, below top of rail	2 ft. 6 in.
Pitch toward lower end in length of pit, at least	6 in.
Thickness of pit wall to support jacking timbers	2 ft. 7 in.
The pit floor should be crowned at the center with a gutter at each side.	

Your Committee concurs with the above conclusions, but calls attention to the possible reduction in clear width due to the structural requirements of providing recesses for radiators, where direct heating is used, and at the same time providing proper support for the rail.

Drop Pit

The requirements of the house determine whether drop pits are necessary and, if so, how many; also whether some of the functions of drop pits may not economically be performed by drop tables or locomotive hoists. This is a matter for the joint consideration of the Mechanical and Engineering Departments.

Usually, an engine house in which running repairs are carried on is furnished with drop pits intersecting two or more engine pits and used for:

Engine trucks.
Engine drivers.
Engine trailer trucks.

and sometimes for tender trucks. Frequently where mallet locomotives are cared for, double driver drop pits are provided intersecting the same engine pits and so spaced that wheels may be dropped simultaneously from both the forward and rear sets of drivers.

The location of drop pits are shown in Exhibit 2.

The general feeling regarding the use of unwheeling hoists in engine houses seems to be that they will prove economical where *all* drivers are to be dropped and work done on them, but where no work is to be done on the wheels or on a few pairs only, the drop pits are more economical. The same remarks apply to the drop table in this case as to the unwheeling hoists.

Of the roads reporting:

37 are not using unwheeling hoists in engine houses, although four of these are using them in shops.

5 are using hoists in engine houses, but none is yet ready to give an opinion as to their relative economy.

Machine and Tool Equipment

The nature and amount of such equipment depend entirely on the extent of the repairs to be made in the engine house.

The Mechanical Division's Committee concluded that the following is the minimum machine and tool allowance for an engine house without a heavy repair shop and your Committee recommends that space adjacent to and connected with the engine house be provided for this allotment of tools.

1—4 in. pipe threading machine.
1—50-ton hydraulic or power press.
2—Double emery grinders.
1—Grindstone.
1—36 in. x 8 ft. planer.
1—36 in. drill press.
3—16 in. lathes, 6 ft. x. 8 ft. bed, one at least of these portable.
1—24 in. x 16 ft. lathe.
1—Lathe with sufficient swing to take the largest piston head used.
1—Bolt cutter up to 1½ in.
1—44 in. vertical boring mold.
1—20 in. drill press.
1—28 in. double head crank shaper.
1—30 in. radial drill press.
1—Double punch and shear 24x36 up to 1½-inch metal.
1—Flanging clamp 10 ft.
1—800 lb. steam hammer.
1—Set of tin shop tools.
2—One man electric welders.
1—Acetylene torch outfit.
Blacksmith forges.
Annealing furnace.

Piping

Piping should be provided for air, steam blower, hot and cold water supply and blow-off from the locomotive boiler. Connections should be provided between alternate stalls except for the blow-off pipe, which should be between each stall; the steam supply near the front end of the boiler, the air, water and blow-off lines near the front end of the fire box.

The blow-off pipe should discharge outside the house.

Steam and hot water piping should be covered with insulated covering material.

Boiler Washout System

A boiler washout system is desirable in an engine house of any size, as the heat from the blown off steam may be used to heat water for washing out and refilling the boiler. The blow-off pipe in this case is led to the washout system reservoir. The washout and refilling line connections are at or near the front end of the fire box.

Legal Requirements

The various states prescribe the clearances required at doors and, in some cases, the sanitary arrangements required. The standards in use by the railroads and the recommended practice of the Association meet the requirements of practically all the states.

Special Agreements

Special agreements with workmen cover usually only sanitary and locker facilities.

Recommended Changes in Manual

Your Committee recommends that the text now appearing in the Manual, 1915 Edition, under the title "Engine House Design" be changed to read as follows. Sections changed are indicated by an asterisk.

Form

*(a) The circular form under ordinary conditions is preferable.

*(b) Special conditions may render a rectangular house desirable, such as restricted location, small number of engines handled, greater ease of providing "Y" than turntable, etc.

(c) At shops where a transfer table is used, a rectangular engine house served by the transfer table may be desirable.

Turntable

(a) The turntables should be long enough to balance the engine when the tender is empty.

*(b) A deck turntable is preferable to a through table when the cost of construction is no greater.

*(c) At important terminals, turntables are most economically operated by mechanical means.

*Where electric power is available, an electric tractor is the most efficient means of operating a turntable. The power wires may be led to the table either underground or overhead.

*Where electric power is not available, a compressed air motor may be used to propel the table. In this case, the locomotive itself usually furnishes the compressed air.

(d) The deck on the turntable should be wide enough to provide a walk on each side and be protected with hand rails.

Turntable Pit

*(a) The turntable pit should be drained and paved.

*(b) The circle wall should be of masonry, with proper supports and fastenings for rails on the coping. A timber coping is considered a proper support and preferable to a rigid masonry coping.

*(c) The circle rail should preferably bear directly on masonry base.

(d) Easy access to the parts of a turntable for the oiling of bearings, painting and inspection should be provided in the design of the turntable pit, unless ample provision is made in the turntable itself.

Door Openings

*The clear opening of entrance doors should not be less than thirteen (13) ft. in width and seventeen (17) ft in height.

Doors

Doors should be easily operated, fit snugly, be easily repaired and maintained, and should admit of the use of small doors.

Tracks

(a) Lead tracks to the turntable should line up with tracks of the engine house where possible.

(b) Tracks should be on a level grade and should be provided with stop blocks.

(c) Special fastenings of the track rails at the circle wall and on the turntable are desirable to prevent movement of the rails, to give good bearing and to lessen the damage from derailed wheels.

Position of Locomotive

In a circular house the locomotive should stand normally with the tender toward the turntable.

***Length of House**

The length of stall along center line of track should be at least twenty (20) ft. greater than the overall length of the locomotive to provide trucking space of ten (10) ft. in width in front of the pilot and space in which to detach the tender and provide a walkway between it and the engine without opening the door.

Materials

(a) The materials used in construction of the house should be non-corrosive, unless proper care be taken to prevent corrosion.

*(b) The additional security against interruption to traffic from fire warrants serious consideration of the use of a fireproof roof or dividing the engine house into units of approximately 10 stalls by the use of division walls of fireproof material.

*(c) Omit.

*(c) The portion of the wall directly in line of the track where the engine is liable to run into it, should be so constructed as to be easily replaced or repaired when damaged.

***Engine Pits**

Engine pits should extend from a point ten (10) ft. from the inner circle columns to a point thirteen (13) ft. from the inner face of the outer circle wall. The clear width should be four (4) ft.; depth below base of rail, minimum two ft. six in. (2 ft. 6 in.) increasing with the slope of the floor of the pit to at least 3 ft. 0 in. The walls should be about two ft. seven in. (2 ft. 7 in.) thick to provide proper support for jacking timbers. The clear width may be reduced a few inches when direct heating is used to permit the provision of recesses in the side walls for radiators and still allow ample support for the rails.

The floor should be convex and the drainage toward the turntable unless topographical conditions dictate otherwise.

***Smoke Jacks**

The smoke jacks should be fixed. The bottom opening should be not less than forty-two (42) in. wide, and long enough to receive the smoke from the stack at its limiting positions, due to the adjustment of the driving wheels to bring the side rods in proper position for repairs. The bottom of the jack should be as low as the engine will allow, and it should be furnished with a drip trough. The slope upward should be uniform to the flue. The area of the cross-section of the flue should be not less than seven (7) sq. ft. The jack should be preferably non-combustible. Wooden jacks properly built are considered reasonably non-combustible.

(This type of jack applies to all houses where regulations will permit. In some cities, where smoke abatement laws are in force, special types of jacks are necessary.)

When the engine house is without a turntable, smoke jacks should be located at each end of each engine space.

*Floors

The floors should be of permanent construction sloped so as to drain properly. The floor around the outer circle and for the outer bay or outer two bays where trucking is carried on and most of the work is done, may advantageously be constructed of wood block, or vitrified brick on a concrete base, while the remainder of the floor between pits may for the sake of economy be of concrete.

*Drop Pits

The number and type of drop pits depends on the purpose for which the particular house is used and the class of power handled.

Ordinarily, a drop pit should be provided for driving wheels and supplemented as required by drop pits for engine truck, trailer, and tender wheels.

At points where considerable work is customarily performed on the wheels, the use of a drop table or unwheeling hoist should be considered.

Heating

(a) Heat should be concentrated at the pits.

(b) The general temperature of the house should be kept between 50 and 60 deg. Fahr.

*(c) The recommended method for heating houses of 10 stalls or over is by hot air driven by fans through permanent ducts located under the floors where practicable. The outlets should be located in the pits under the engine portion of the pits, and fitted with dampers to shut off the heat when necessary. Temperature of the hot air at the pits should be 130 to 150 deg. Fahr.

The fan and distributing system should have a capacity for changing the air from 3 to 4 times an hour. The fresh air should be taken from outside the building. The fan intake should be so designed as to permit the use of all fresh air, all inside air, or part fresh and part inside air. A certain amount of recirculation, depending entirely on conditions, is permissible, particularly when the doors stand open for any length of time.

*(d) In a small house, or in a larger house in some climates, analysis may show the direct system of heating to be more desirable. In such a case, the vacuum return system should be used. Radiators should be placed in the pits and properly protected from falling parts, and also on the outer walls and end or fire walls. Radiators on the outer walls should be so located as to be clear of the path an engine would take in going through the outer wall.

Windows

(a) The disadvantages of skylights are so much greater than their advantages as to make them undesirable.

*(b) Windows in the outer walls should be made as large as practicable with the largest glass or light area consistent with the strength of the structure. In general, the lower sill should be not more than four (4) ft. from the floor and the space between window frames and columns or pilasters and girders only that necessary to secure the window frames.

Windows in doors, when provided, should be furnished with wire glass.

***Electric Lighting**

General distribution of illumination should be provided either by:

(a) Individual lights between pits arranged to avoid shadows, 300 to 500 watts to a stall, or;

(b) Flood lights on the outer and inner circle walls so arranged as to diffuse rays, eliminate the glare common with flood lights and avoid deep shadows. Usually 2 100-watt lamps on the outer wall and 1 60-watt lamp on the inner wall are sufficient.

Either system should be supplemented by plug outlets for drop cord lamps in each alternate space between pits.

Piping

*(a) The engine house should be provided with piping for air, steam and water supply and for boiler blow-off. The latter line should discharge outside the house and when a boiler washout system is installed, should discharge into the blow-off reservoir.

*(b) A boiler washout and refilling system is ordinarily desirable to provide hot water for washing and refilling and to make use of the steam and water blown off from locomotive for this purpose.

*(c) The steam outlet should be located near the front end of the boiler. The blow-off line, the air, washout and refilling water and cold water connections should be near the front end of the fire box. Connections should be provided in alternate spaces between stalls, except for the blow-off line to which connections should be provided between each stall.

*(d) Steam and hot water piping should be insulated.

***Machine and Tool Equipment**

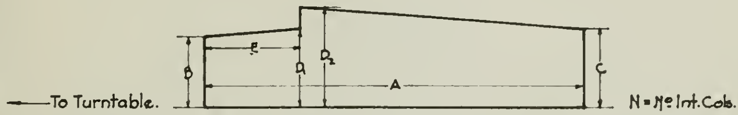
The space provided for machine tools and the extent of machine and tool equipment will depend entirely upon the location and method of operation of the house and must be made a subject of study for each house.

***Mechanical Handling Devices**

Consideration should be given in the design of an engine house to the use of traveling cranes, jib cranes or monorails and provision made in the design of the structure for future installation if such is considered probable.

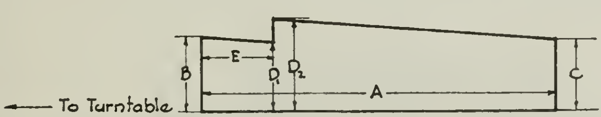
Exhibit C

DIAGRAMS OF ENGINE HOUSE CROSS-SECTIONS



RAILROAD	LOCATION	TYPE	A	B	C	D1	D2	E	N
C. & N.W.	Standard	Frame	97'-9"	19'-0"±	21'-2"	20'-10"	25'-6"±	28'-0"	3
G.N.	"	"	116'-0"	20'-3"	22'-9"	21'-3"	27'-11"	44'-6"	4
"	"	"	103'-5"	20'-3"	22'-3"	21'-0"	27'-11"	43'-6"	4
U.P.	Council Bluffs	"	95'-3"	18'-3"	26'-7"	21'-9"	33'-6"	25'-0"	3
A.T. & S.F.	Std. Low	Rein. Conc.	90'-4 1/2"	18'-11 3/8"	24'-10 1/2"	20'-1 1/8"	27'-6"	27'-6 1/2"	3
I.C.	Standard	Frame	98'-2"	19'-6"	24'-0"	22'-0"	29'-6"	26'-6"	3
E.J.& E.	E. Joliet	Rein. Conc.	86'-1"	23'-0"	22'-3"	25'-1"	31'-9"	25'-9"	3
" " (C.L.S.& E.)	Gary.	Frame	87'-3"	22'-10"	22'-1 3/16"	25'-4"	32'-0"	25'-0"	3
D.& H.	Oneonta, N.Y.	Rein. Conc.	100'-8"	23'-9 3/4"	30'-6 1/2"	24'-10 3/8"	33'-1 1/8"	23'-7"	3
U.P.	Council Bluffs	Frame	114'-0"	28'-6"	25'-0 1/4"	30'-6"	34'-6"	24'-7"	4
L. & N.	Paris, Tenn.	Steel Frame Wood Roof.	100'-0"	22'-0"±	31'-4 1/2"	24'-8"	35'-0"±	33'-4"	2
" "	Radnor, "	" "	100'-0"	20'-6"±	31'-4"±	22'-4 5/8"	35'-0"±	33'-4"	2
C.B. & Q.	Galesburg Ill.	Wood	98'-5"	19'-2"±	20'-7"±	20'-7"	30'-8 1/2"	26'-0"	3
" " " "	Lincoln, Neb.	Rein. Conc. Unit Sys.	100'-0"	20'-9"±	20'-8"±	21'-6"	28'-2"	24'-6"	4
C.M. & St.P.	Standard	Wood	96'-0"	18'-7"±	20'-0"	18'-11"	25'-10"	26'-0"	3
C. of N.J.	Communipaw	Rein. Conc.	101'-2"	18'-10"	20'-10"	20'-0 1/2"	27'-9"	29'-0"	3
" "	" "	" "	91'-0"	18'-10"	20'-10"	20'-0 1/2"	27'-9"	29'-0"	3
" "	Ashley.	Frame	85'-6"	18'-0"	24'-10"	20'-10"	29'-0"	35'-1"	4
S.P.	Tracy, Col.	Rein. Conc.	92'-7"	19'-4"	24'-5"	20'-6"	28'-2"	21'-9"	3

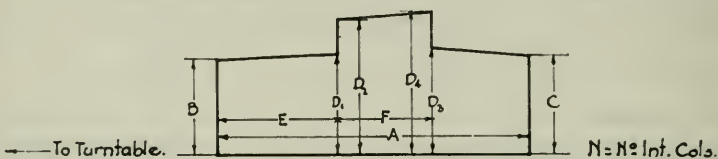
Rank 10 Frame 1
6 Concrete 1 & 2
1 Steel



RAILROAD	LOCATION	TYPE	A	B	C	D1	D2	E	N
P.M.	New Buffalo, Mich.	Frame	100'-6"	23'-5"	27'-6"	22'-4"	31'-7"	23'-0"	4
P.& L.E.	Hasleton, Pa.	Steel Frame	101'-0"	22'-0"	23'-0"	19'-0"	31'-6"	24'-0"	3

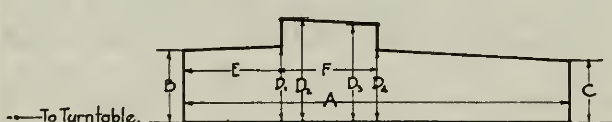
Exhibit C

Diagrams of Engine House Cross-Sections

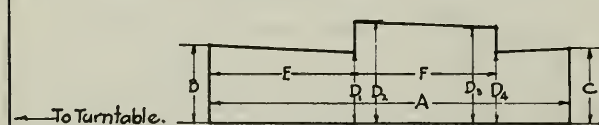


RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	E	F	N
N.C. & St.L.	Mills Park Yard	Rein Conc	95'-9"	19'-0"	20'-3"	21'-2"	28'-3"	21'-7"	27'-8"	35'-9"	30'-0"	2
" " "	Hollow Rock	Frame	96'-0"	19'-0"	21'-10"	22'-3"	31'-0"	25'-3"	33'-0"	38'-3"	19'-10"	4
T. & O.C.	W. Columbus	Rein. Conc.	110'-0"	19'-6"	20'-10"	20'-5"	28'-9"	21'-8 1/2"	31'-4"	29'-4"	58'-0"	3
D. & R.G.	Pueblo.	" "	106'-4"	24'-0"	23'-0"	25'-6"	26'-0"	25'-6"	28'-0"	31'-0"	29'-4"	3
B. & O.	Cumberland	Frame	109'-0"	20'-10"	21'-4 3/4"	22'-0 1/2"	29'-0 1/2"	27'-9 1/2"	35'-6 1/2"	23'-6"	45'-2"	4
Sou.	Big Stone Gap	Rein. Conc	116'-0"	19'-9"	23'-4"	23'-8"	30'-4"	24'-10"	31'-9"	58'-0"	29'-0"	3
P. & R.	Erie Ave Phila	" "	90'-0"	19'-3"	24'-3 1/2"	21'-10 1/2"	30'-11 1/2"	26'-10 1/4"	35'-6 3/4"	31'-6"	27'-9"	2
"	" " "	" "	109'-9 1/2"	19'-3"	22'-2"	21'-10 1/2"	30'-11 1/2"	26'-10 1/4"	35'-6 3/4"	31'-6"	27'-9"	3

Rank 2 Frame
6 Concrete 1 & 2



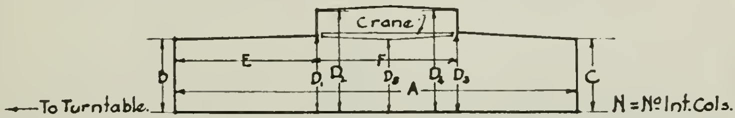
RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	E	F	N
D.L. & W.	Gravel Pl. Pa.	Frame	90'-8 1/2"	26'-0"	23'-5"	26'-7 1/2"	32'-9 1/2"	34'-6"	28'-2 1/2"	28'-0"	26'-0"	3
St.L. & S.F.	Afton, Okla	" "	108'-9"	23'-0"	20'-6"	24'-3"	32'-5"	29'-4"	21'-2"	36'-3 1/2"	54'-10 1/2"	5
Penn.	Standard	Rein. Conc	120'-0"	22'-2 1/2"	22'-2 1/2"	28'-8"	37'-6"	33'-2"	24'-4"	60'-0"	40'-0"	5



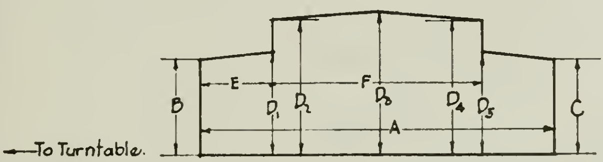
RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	E	F	N
P.M.	Plymouth	Frame	109'-6"	25'-1"	24'-10"	22'-7 1/2"	34'-10"	33'-1"	21'-3"	47'-6"	43'-4"	4

Exhibit C

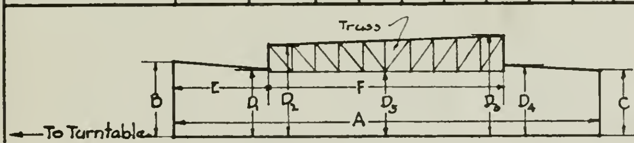
Diagrams of Engine House Cross-Sections



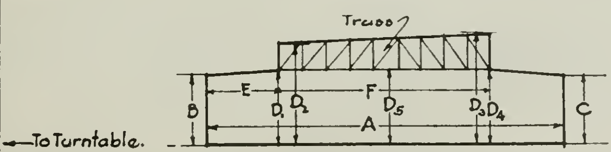
RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	D_5	E	F	N
C. of Ga.	Columbus, Ga.	Rein. Conc.	121'-0"	23'-4"	29'-5"	27'-4"	39'-2"	27'-4"	39'-2"	28'-5"	43'-7"	43'-6"	2
A.T. & S.F.	Std. High	" "	132'-0"	18'-11 11/32"	23'-0"	21'-6"	34'-1"	25'-6"	34'-1"	26'-3 1/16"	43'-7 1/2"	46'-4"	4
" "	" "	" "	92'-0"	18'-11 11/32"	—	21'-6"	34'-1"	—	34'-1"	26'-3 1/16"	43'-7 1/2"	46'-4"	2
U. P.		Frame	95'-3"	20'-6"	24'-0"	22'-6"	35'-9"	24'-9"	35'-9"	24'-4"	40'-6"	34'-0"	3



RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	D_5	E	F	N
B. & M.	East Deerfield	Frame	100'-0"	19'-3"	19'-3"	20'-6"	30'-5"	31'-4"	30'-3"	20'-6"	20'-10"	61'-9"	4
D. L. & W.	Elmira, N.Y.	" "	85'-0"	22'-10"	22'-10"	24'-9 1/2"	31'-0"	32'-7"	31'-0"	24'-9 1/2"	23'-11"	38'-2"	3
M. K. & T.	Okla. City	" "	103'-6"	21'-0"	19'-0"	20'-0"	29'-0"	30'-0"	29'-0"	22'-9"	21'-0"	42'-0"	4



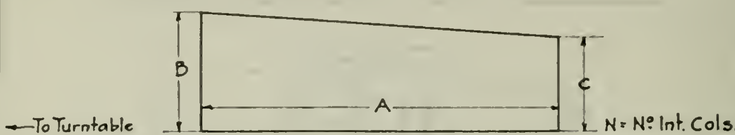
RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	D_5	E	F	N
N. Y. C.	Standard	Frame	110'-0"	20'-11"	20'-6"	19'-3"	28'-4"	31'-1"	21'-4"	18'-0"	25'-0"	64'-0"	2
" " "	" "	" "	125'-0"	25'-11"	23'-4"	24'-5"	34'-1"	37'-5"	24'-9"	23'-2"	26'-0"	75'-0"	2



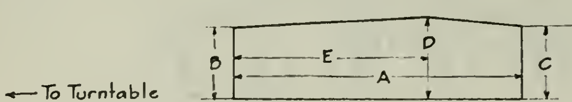
RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	D_5	E	F	N
C. & O.	Logan Yard	Frame	115'-8"	20'-1"	23'-10"	21'-1"	30'-0"	33'-0"	21'-1"	20'-0"	20'-0"	74'-6"	2

Exhibit C

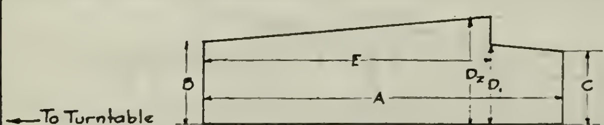
Diagrams of Engine House Cross-Sections



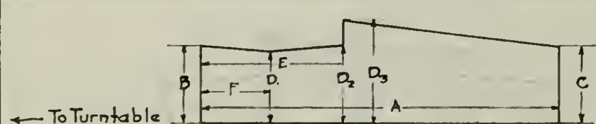
RAILROAD	LOCATION	TYPE	A	B	C	N
C.N.	Standard	Frame	100'-0"	24'-9"	18'-6"	4
C.&W.I.	Clearing Yard	"	90'-1"	30'-0"	23'-0"	3
N.Y.N.H.&H.	So. Worcester	"	105'-5"	25'-2"	20'-2"	5
" " "	Cedar Hill	"	95'-6"	25'-2"	20'-2"	3
M.C.	Niles, Mich.	"	101'-2"	30'-7"	22'-0½"	4
L.E.&W	Lima, O.	"	100'-0"	30'-7½"	20'-7"	4
C.P.	Standard	"	88'-5"	25'-3"	19'-0	3



RAILROAD	LOCATION	TYPE	A	B	C	D	E	N
C. of Ga.	Macon, Ga.	Frame	85'-4"	26'-4"	28'-9	31'-1"	57'-0"	2
C.G.W.	Standard	"	99'-6"	19'-6"	19'-6"	24'-0	54'-0"	3
Sou.	Pomona, N.C. Alexandria, Va.	Reinf Conc.	99'-3"	19'-6"	22'-6"	25'-1	75'-0"	3



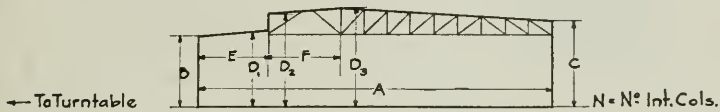
RAILROAD	LOCATION	TYPE	A	B	C	D.	D_2	E	N
B.&O.	Grafton, W.Va.	Brick	109'-6"	22'-3"	19'-2⅞"	20'-5"	30'-0"	91'-4"	4



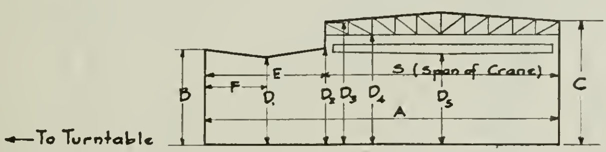
RAILROAD	LOCATION	TYPE	A	B	C	D.	D_2	D_3	E	F	N
C.R.I.&P.	Burr Oak, Ill.	Frame	100'-5	19'-4"	21'-6"	18'-2"	19'-8"	26'-8	43'-0	21'-9"	4

Exhibit C

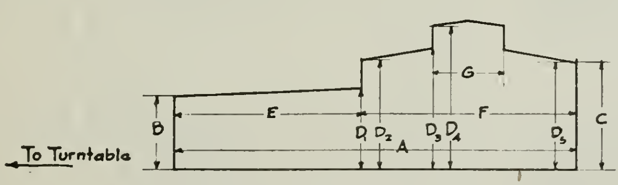
Diagrams of Engine House Cross-Sections



RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	E	F	N
N.P.	St. Paul, Minn.	Frame	114'-6"	21'-0"	30'-6"	23'-9"	31'-0"	34'-0"	32'-0"	21'-0"	2



RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	D_5	E	F	S	N
Penn.	Type A	Steel	115'-10"	20'-9"	39'-6"	20'-7"	21'-4"	39'-8"	30'-0"	22'-6"	36'-0"	19'-0"	74'-4½"	2



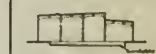
RAILROAD	LOCATION	TYPE	A	B	C	D_1	D_2	D_3	D_4	D_5	E	F	G	N
N. & W.	Standard	Brick.	114'-6"	21'-9"	34'-2"	25'-6"	34'-6"	36'-2"	44'-0"	34'-6"	48'-4"	66'-8"	24'-0"	3

C. to C. posts front 14'-0"
" " " stalls back 26'-0"

ENGINE HOUSE DATA

TABULATION OF INFORMATION FROM QUESTIONNAIRE AND PLANS BY AMERICAN RAILWAY ENGINEERING ASSOCIATION COMMITTEE ON SHOPS AND LOCOMOTIVE TERMINALS

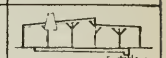
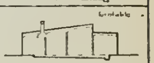
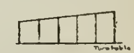
SHEET No 1

RAILROAD	LOCATION	STALLS		CLASS OF POWER	RADIUS OF TURNTABLE	DISTANCE ℄ TURNTABLE TO ℄ INNER COLUMNS	DISTANCE ℄ INNER COLUMNS TO INSIDE FACE OUTER WALL	TRACK ANGLE	SMOKE JACKS			DOORS			TYPE OF WINDOWS	FRAME WORK	ROOF	FLOOR	FIRE WALLS	TYPE OF HEAT	VENTILATION	ENGINE PITS					DROP PITS (DISTANCE TO ℄ FROM INSIDE OUTER WALL)			MECHANICAL HANDLING DEVICES	SECTION
		NUMBER	LENGTH						TYPE AND SIZE	DISTANCE TO ℄ FROM INSIDE OUTER WALL	CLEARANCE ABOVE T of R	TYPE	CLEAR WIDTH	CLEAR HEIGHT								LENGTH	DISTANCE TO END FROM INNER COLUMN	DISTANCE TO END FROM INSIDE OUTER WALL	MINIMUM DEPTH	THICKNESS OF WALLS	DRIVER	FRONT	TRAILER		
A. T. & Sa. Fe	LAS VEGAS, N.M.	34	90-11	Mallet & Santa Fe	42-6	107-8	90-4½	6° 55 23		17		Swing Wood	12-10	18-0	Wood Sash	Reinforced Concrete	Reinforced Concrete Slab	Paving blk on 4" Conc base & 1" sand cushion	None	Direct	Pivoted Sash	66-6	11-11	11-11	2-4	2-6	53-5	17-0		None	
B. & O.	GRAFTON, W.VA.	12	110-0	Mallet Mikado & Smaller	50	108-6	109-6	7° 34 38	Cast Iron	27-8	16	Rolling Wood	13-5	16-6	Steel Sash	Wood	1⅞" Sheathing	Wood block on 2" sand	13" Brick wall of old 11 stall house used as firewall	Indirect	Pivoted Sash Clerestory	88-6	8	13	2-6	2-9				Locomotive Hoist	
B. & O.	CUMBERLAND, MD.	31	109-6	Mallet Mikado & Smaller	50	104-7	109	7° 49 34	Cast Iron	27-8	16-3	Rolling Wood	13-3	16-4	Steel Sash	Wood	1¾" Planks	Wood block Conc base	13" Brick 8-13-10 Stalls	Indirect	Louvres in Monitor	88	8	13	2-6	2-9	32-7	20	58-3	Jib Cranes	
B. & M.	E. DEERFIELD, MASS.	24	100-6	Switch Eng to 2-10 2	50	134	100-0	6 15	Wood	21-9	16	Swing Wood	13-4	16	Steel Sash	Wood	3" Planks	Concrete	13" Brick at each 8 Stalls	Indirect	Pivoted sash	75	12-6	13	2-0	2-2	41-9			None	
B. R. & P.	E. SALAMANCA, N.Y.	12	114-3			85-0		10°	Cast Iron	19-10	16-0		14-0	17-5	Steel sash	Wood & Concrete	Wood & Concrete	Concrete	Brick Wall 5-6-7 Stalls	Indirect	Sash in Monitor	96-3		11	2-4		37-3		58-1	15 Ton Crane	
C. N.	SASKATOON, SASK.	15	98-11	Mikado 78-2" long	43	95-8	98-5	8° 26	Wood	23-8	16-6	Swing Wood	13	17	Wood Sash	Wood	2" T&G	Cinders	13" Brick at each 5 Stalls	Direct	Louvres	63	17-6	17	2-4		47-10	22-0	70-7	None	
C. P.	STANDARD No. 5		88-11	All Classes	45	123-5	88-5	6° 31 30	Wood	16-6	Var	Swing Wood	13	17	Wood Sash	Wood	2x3 on edge	Concrete Wood Block Mastic	13" Brick	Direct & Indirect	Hill ventilators	67	8	13-8	2-4		47-6	24-3	69	None	
C. of GA.	MACON, GA.	32	85-10	Mikado Mountain & Smaller	40	130	85-4	6°	Cast Iron	19	18-6	Swing Wood	12-7	18	Wood Sash	Wood	2" Sheathing	Wood block Conc base	13" Brick 8-13-9 Stalls	Indirect	15" Ventilators	60	12	13	2-2	1-5	42-3			Jib Cranes	
C. of GA.	COLUMBUS, GA.	20	121-9	Mikado Mallet 2-8-8 Mountain & Smaller	50	146-4	121-0	5° 49 58	Cast Iron	27-2	17-6	Wood	13	17-6	Wood Sash	Concrete	Concrete	Wood block Conc base	None	Direct	Pivoted sash in Monitor	95-3	11-4	14-4	2-6	2-0	51-7			Crane	
C. of N. J.	COMMUNIPAW, N.J.	34	101-9	Freight 50% Passenger 20% Switching 30%	50	138-11	101-2	5° 48 23	Cast Iron	23	16-9	Swing Wood	13-2	16-2	Steel Sash	Concrete	Concrete & Tile	Concrete	None	Indirect	Pivoted Sash	65		13	2-6	1-8	45	25-7		Jib Cranes	

ENGINE HOUSE DATA

TABULATION OF INFORMATION FROM QUESTIONNAIRE AND PLANS BY AMERICAN RAILWAY ENGINEERING ASSOCIATION COMMITTEE ON SHOPS AND LOCOMOTIVE TERMINALS

SHEET Nº 2

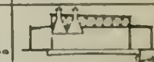
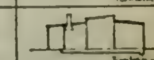
RAILROAD	LOCATION	STALLS: NUMBER	STALLS: LENGTH	CLASS OF POWER	RADIUS OF TURNTABLE	DISTANCE ℄ TURNTABLE TO ℄ INNER COLUMNS	DISTANCE ℄ INNER COLUMNS TO INSIDE FACE OUTER WALL	TRACK ANGLE	SMOKE JACKS: TYPE AND SIZE	SMOKE JACKS: DISTANCE TO ℄ FROM INSIDE OUTER WALL	SMOKE JACKS: CLEARANCE ABOVE T of R	DOORS: TYPE	DOORS: CLEAR WIDTH	DOORS: CLEAR HEIGHT	TYPE OF WINDOWS	FRAME WORK	ROOF	FLOOR	FIRE WALLS	TYPE OF HEAT	VENTILATION	ENGINE PITS: LENGTH	ENGINE PITS: DISTANCE TO END FROM ℄ INNER COLUMN	ENGINE PITS: DISTANCE TO END FROM INSIDE OUTER WALL	ENGINE PITS: MINIMUM DEPTH	ENGINE PITS: THICKNESS OF WALLS	DROP PITS (DISTANCE TO ℄ FROM INSIDE OUTER WALL): DRIVER	DROP PITS: FRONT	DROP PITS: TRAILER	MECHANICAL HANDLING DEVICES	SECTION
D.&R.G.	PUEBLO, COL.	49	117'-2"	Santa Fe Mallet & Smaller	50'	117'-7"	106'-4"	6° 30'	Wood	21'-6"	18'-0"	Swing Wood	20'-0"	18'-0"	Wood	Wood	Concrete	Brick	None.	Indirect	Pivoted Sash	68'-0"	16'-0"	20'-0"	7'-6"	3'-0"	45'-0"			None.	
D.M.&N.	N. PROCTOR, MINN			Santa Fe Mallet					Cast Iron			Wilson Rolling Lift			Steel Sash		Reinforced Concrete	Concrete		Direct										None.	
E.J.&E.	E. JOLIET, ILL	17	85'-0"	Road & Switch Freight Engines	40'-0"	28'-11"	86'-1"	10°	Transite Asbestos	24'-6"	15'-2"	Swing Wood	13'-0"	17'-5"	Wood sash	Reinforced Concrete	Reinforced Concrete	Concrete	None	Indirect	Piv. Wind. Transom	54'-0"	10'-9"	21'-0"	2'-0"	1'-6"				None	
E.J.&E.	GARY, IND.	20	86'-6"	Road & Switch Frt Engines	50'-0"	48'-7"	87'-3"	6°	Transite Asbestos	16'-9"	15'-2"	Swing Wood	14'-0"	17'-6"	Wood Sash	Wood	2"x6" Rafters	Brick	13" Brick 6 & 14 Stalls.	Indirect	Pivoted Sash Clerestory	54'-0"	11'-6"	21'-0"	2'-0"	1'-6"	34'-0"		63'-9"	None.	
E.P.& S.W.	TUSCON, ARIZ.	11	92'-6"	Too Small for new power	40'-4"	100'-0"	92'-0"	8°	Ingot Iron	19'-6"	17'-6"	Swing Wood	13'-0"	17'-5"	Wood Sash	Reinforced Concrete	Reinforced Concrete	Well tamped Dirt	None	Direct	Louvres	60'-0"	12'-6"	16'-9"	2'-6"	1'-2"	39'-5"				
G.N.	STANDARD		114'-11"	Mallets.	50'-0"	111'-11"	114'-5"	7° 12°	Wood Asbest	26'-0"	16'-6"	Swing Wood	13'-2"	17'-6"	Wood Sash	Wood	1¾" Boards	Wood block Conc. base	13" Brick Every 5 Stalls	Indirect	Louvres in Clere Story	90'-0"	12'-3"	12'-3"	2'-3"	2'-9"	39'-9"		65'-9"	Monorail	
G.N.	WOLF POINT, MONT.	25	103'-11"	Mikado & Smaller	50'-0"	111'-11"	103'-5"	7° 12°	Wood-Asb.	20'-0"	16'-6"	Swing Wood	13'-2"	17'-6"	Wood Sash	Wood	1¾" Boards	Wood block Conc base	13" Brick Every 5 Stalls	Indirect	Sash in Clere Story	85'-0"	8'-2"	9'-3"	2'-3"	2'-3"	36'-1"		64'-11"	Monorail	
I.C.	PADUCAH, KY	36	98'-8"	Mikado	50'-0"	114'-6"	98'-2"	7° 2°	Asbestos	26'-0"	16'-6"	Swing Wood	13'-2"	17'-0"	Wood Sash	Wood	1⅝ D&M	Wood block Cinders	13" Brick 12 Stalls ea	Indirect	Windows in Clere Story	75'-0"	7'-11"	15'-3"	2'-6"	3'-3"	48'-4"	27'-4"	57'-6"	None.	
L.V.	SAYRE, PA.	46	95'-5"		50'-6"	107'-1½"	94'-9½"	7° 12°	Cast Iron	19'-0"	6'-5⅜"	Steel Rolling	12'-0"	17'-6"	Steel Sash	Concrete	Conc. and Tile.	Mastic Conc. Base		Indirect	Pivoted Sash in Clere Story	74'-0"	8'-8"	11'-0"	2'-0"	1'-0"		17'-8"	50'-6"	None.	
L.E.&W.	LIMA, O.	21	100'-5"	Std Light Mikado	45'-0"	133'-9"	100'-0"	6° 25° 43°	Cast Iron	23'-6"	16'-6"	Wood Swing	14'-0"	17'-1"	Steel Sash	Wood	2"x6" Sheath	Brick on Conc. Base	9" Brick		Pivoted Sash.	72'-0"	12'-0"	16'-0"	2'-6"	2'-8"	45'-0"	28'-0"	55'-0"	None.	

ENGINE HOUSE DATA

TABULATION OF INFORMATION FROM QUESTIONNAIRE AND PLANS BY AMERICAN RAILWAY ENGINEERING ASSOCIATION. COMMITTEE ON SHOPS AND LOCOMOTIVE TERMINALS.

SHEET № 3

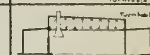
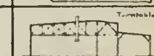
Railroad	Location	Stalls: Number	Stalls: Length	Class of Power	Radius of Turntable	Distance ℄ Turntable to ℄ Inner Columns	Distance ℄ Inner Columns to Inside Face Outer Wall	Track Angle	Smoke Jacks: Type and Size	Smoke Jacks: Distance to ℄ from Inside Outer Wall	Smoke Jacks: Clearance above T of R	Doors: Type	Doors: Clear Width	Doors: Clear Height
C. of N.J.	ASHLEY, PA.	18	85'11"		35'	65'5"	85'6"	11° 59' 52"	Cast Iron	21'7"	15'4"	Swing Wood	12'9"	15'11"
C.&O.	LOGAN YARD, W.VA.	5	116'3"	2-6-6-2 Mallet	50'	105'9"	115'9"		2 Asbestos	27'9" 43'3"	16'0"	Swing Wood	13'	17'
C.&W.I.	(CLEARING YARD) CHICAGO, ILL.	20	90'7"	Switch Engines	42'6"	103'7"	90'1"	7° 30'	Cast Iron	23'5"	16'6"	Swing Wood	12'6"	17'2"
C.&N.W.	(CHASE YARD) MILWAUKEE, WIS.	35	98'4"	Switch Pacific Mikado	47'6"	129'6"	97'9"	6°	Asbestos	19'10"	16'	Swing Wood	12'8"	17'1"
C.B.&Q.	GALESBURG, ILL.	16	98'11"	Largest type Freight	50'	138'	98'5"	6° 24'	Cast Iron	17	17'	Swing Wood	14'	17'
C.G.W.	E. STOCKTON, ILL.	15	100'0"	10 Wheel Pacific Mikado Santa Fe	45'	109'11"	99'6"	8°	Asbestos	19'5"	16'6"	Swing Wood	13'2"	17'2"
C.R.I.&P.	BURR OAK, ILL.	20	100'11"		45'	125'4"	100'5"	6° 25' 71"		21'6"	16'6"	Swing Wood	13'4"	17'
C.M.&St.P.	N. MACGREGOR, IA.	22	95'1"	Pacific 4-6-2 Mikado 2-8-1	45'	126'8"	94'7"	6° 28' 37"	Cast Iron	19'	16'6"	Swing Wood	13'5"	16'6"
D.&H.	ONEONTA, N.Y.	27	101'4"	All Classes	37'6"	131'3"	100'8"	6° 19'	Asbestos	25'11"	16'6"	Swing Wood	13'1"	17'1"
D.L.&W.	GRAVEL PLACE, PA.	17	91'7½"	4-6-2 2-8-2	45'	119'6"	90'5½"	7° 30'	Asbestos	17'6"	16'0"	Swing Steel	14'6"	16'1"

Railroad	Type of Windows	Frame Work	Roof	Floor	Fire Walls	Type of Heat	Ventilation	Engine Pits: Length	Engine Pits: Distance to End from ℄ Inner Column	Engine Pits: Distance to End from Inside of Outer Wall	Engine Pits: Minimum Depth	Engine Pits: Thickness of Walls	Drop Pits (Distance to ℄ from Inside Outer Wall): Driver	Drop Pits: Front	Drop Pits: Trailer	Mechanical Handling Devices	Section
C. of N.J.	Wood Sash	Wood Posts	2" Y.P.T.&G.	6" Concrete on 12" Cinders	None	Direct	Pivoted sash	63'	12'7"	5'11"	2'6"	1'8"	30'	38'		None	
C.&O.	Wood Sash	Wood	7/8" Sheathing	Concrete	None	Indirect	Pivoted sash	88'	11'6"	16'3"	2'6"	2'3"	59'3"	38'9"		Monorail Crane	
C.&W.I.	Wood Sash	Wood	1¾" Boards	Paving Brick on sand	13" Brick 10 Stalls ea.	Direct	Pivoted sash	66'	8'6"	15'	2'6"	2'	34'			None	
C.&N.W.	Wood Sash	Wood	3" Sheathing	Paving brick on sand	13" Brick 10-12 13 Stalls	Direct	Pivoted sash	71'10"	11'6"	10'3"	2'2"	2'	38'10"	31'1"		None	
C.B.&Q.	Steel Sash	Wood	2"6" Shiplap	Brick Paving	None	Indirect	Louvres.	77'4"	10'6"	10'6"	2'3"	1'8"	43'	24'0"		None	
C.G.W.	Wood Sash	Wood	1⅝" Boards	Br. paving 6" Cinders	13" Brick 5 Stalls ea.	Indirect	Triple Hung	77'	6'	16'	2'3"	1'5"	54'0"	28'6"		None	
C.R.I.&P.	Steel Sash	Wood	Wood	Cinders	13" Brick 10 Stalls ea.	Indirect	Pivoted sash	74'	11'8"	14'7"	2'6"		33'11"			None	
C.M.&St.P.	Wood Sash	Wood	Gypsum	Brick	13" Brick 11 & 12 Stalls	Indirect	Pivoted sash	73'	10'6"	8'6"	2'6"	2'7"	54'	20'	64'	None	
D.&H.	Wood Sash	Reinforced Concrete	Concrete & Tile	Concrete	13" Brick 7-14-21-27 Stalls	Direct	Pivoted sash	71'4"	9'4"	20'	2'6"	1'8"				None	
D.L.&W.	Wood Sash	Concrete	1¼" T.&G.	Wood block	13" Brick 8x9	Direct	Louvres	73'1"	4'6"	12'11"	3'	2'0"				None	

ENGINE HOUSE DATA

TABULATION OF INFORMATION FROM QUESTIONNAIRE AND PLANS BY AMERICAN RAILWAY ENGINEERING ASSOCIATION COMMITTEE ON SHOPS AND LOCOMOTIVE TERMINALS

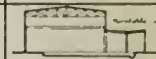
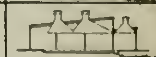
SHEET No. 4

Railroad	Location	Stalls		Class of Power	Radius of Turntable	Distance ℄ Turntable to ℄ Inner Columns	Distance ℄ Inner Columns to Inside Face Outer Wall	Track Angle	Smoke Jacks			Doors			Type of Windows	Frame Work	Roof	Floor	Fire Walls	Type of Heat	Ventilation	Engine Pits					Drop Pits (Distance to ℄ from Inside Outer Wall)			Mechanical Handling Devices	Section
		Number	Length						Type and Size	Distance to ℄ from Inside Outer Wall	Clearance above T. of R.	Type	Clear Width	Clear Height								Length	Distance to End from ℄ Inner Column	Distance to End from Inside Outer Wall	Minimum Depth	Thickness of Walls	Driver	Front	Trailer		
L. & N.	PARIS, TENN.	14	100'-4½"	Heavy Pac. Mikado & Switch	37'-0"	125'-10"	100'-0"	6° 44' 40"	Cast Iron	28'-11"	16'-0"	Swing Wood	14'-0"	16'-0"	Steel Sash	Steel Columns	1⅝" T. & G.	Concrete	None	Direct	Pivoted Sash	65'-0"	15'-0"	20'-0"	2'-8"	3'-0"	49'-5"	26'-0"		10 T. Traveling Crane	
M. C.	NILES, MICH.	30	101'-8"	All Classes	50'-0"	146'-4"	101'-2"	5° 54' 6"	Cast Iron	21'-5"	16'-1"	Swing Wood	14'-2"	16'-2"	Wood Sash	Rein Conc.	2"x6" Boards	Concrete	13" Brick between 11-12 20-21 Stalls	Direct	Louvres	82'-0"	15'-0"	11'-0"	3'-0"	2'-2½"	46'-0"	37'-0"		None	
M. St. P. & S. S. M.	SHOREHAM	48	80'-6"	Mikado & Pacific	50'-0"	123'-0"	80'-0"	6° 25' 45"	Cast Iron	24'-0"		Swing Wood	12'-0"		Wood Sash		Wood	Concrete	13 Brick 1 in 16 Stalls	Direct	Roe Ventilator	65'-10"	7'-4"	17'-0"	2'-3"	1'-8"	52'-7"	22'-4"		None	
M. K. & T.	OKLAHOMA CITY	10	104'-0"	Heavy Mikado	50'-0"	139'-0"	103'-6"	5° 52'	Asbestos	23'-0"	16'-3"	Swing Wood	15'-0"	17'-0"	Steel Sash	Wood	Wood	Vitro Pav. Block	None	Direct	Louvres in Monitor	79'-0"	7'-0"	17'-6"	2'-9"	3'-0"	50'-0"			None	
N. C. & St. L.	HOLLOW ROCK JCT.	8	96'-6"	Mallet Mikado Smaller	45'-0"	106'-7"	96'-0"	8° 6' 52"	Asbestos			Swing Wood	14'-0"	17'-0"	Steel Sash	Wood	2"x6" Board		None		Louvres in Monitor	68'-0"	12'-5"	15'-0"			55'-0"			None	
N. Y. C.	WATERTOWN, N.Y.	30	125'-6"	Heavy Freight & Passenger	50'-0"	126'-5½"	125'-0"	6° 48'	C. I. & Asbestos	34'-6"	16'-0"	Swing Wood	14'-4"	17'-2"	Wood Sash	Wood	2"x10" Wood	Concrete	13" Brick Every 8 Stalls	Indirect	Pivoted Sash in Monitor	89'-0"	9'-0"	27'-0"	3'-0"	1'-8"	48'-0"	37'-2"	89'-0"	Monorail	
NY. N.H. & H.	So. WORCESTER	7	105'-10"	Santa Fe Heavy Mikado	47'-6"	93'-5"	105'-5"	8° 10' 54"	Cast Iron	21'-9"	15'-6"	Rolling Wood	12'-6"	17'-0"	Wood Sash	Wood	2" Boards	Concrete	None	Direct	Monitor	83'-0"	10'-6"	12'-0"	2'-6"	2'-0"	52'-6"	52'-6"		None	
NY. N.H. & H.	CEDAR HILL (N.H.) CON.	18	96'-0"	Santa Fe Heavy Mikado	47'-6"	93'-5"	95'-6"	8° 10' 54"	Cast Iron	16'-6"	15'-6"	Rolling Wood	12'-6"	17'-0"	Steel Sash	Wood	Wood	Concrete Cinders	10" T. C. Wall 6-9-3	Indirect	Monitor	79'-0"	8'-6"	8'-0"	2'-6"	2'-0"	52'-2"	34'-2"		None	
N. & W.	W. ROANOKE YD., VA.	40	115'-0"	U.S. Std. Mallet	57'-6"	96'-7¼"	114'-6"	8° 18' 11"	Cast Iron	27'-9"	16'-10"	Wood Swing	13'-1¼"	17'-1"	Wood Sash	Wood	⅞" Sheathing	Lime Stone Screenings	2 13" Brick in Circle	Salamander	Monitor Pivoted Sash in clere Story	98'-0"	2'-0"	14'-6"	3'-9"	2'-0"	41'-3" 61'-8"	16'-11"	74'-1"	Crane	
N. P.	ST. PAUL MIN.	35	115'-0"	Mallet	50'-0"	134'-3"	114'-6"	6°	Cast Iron	43'-0"	17'-6"	Wood Swing	13'-0"	17'-7¾"	Steel	Wood	2"x8" Boards	Brick on sand cushion	13" Brick each 6 Stall	Direct	Ventilators & Pivoted Sash in clere Story	97'-8"	8'-6"	13'-10"	3'-0"	2'-6"	47'-0"	35'-6"		None	

ENGINE HOUSE DATA

TABULATION OF INFORMATION FROM QUESTIONNAIRE AND PLANS BY AMERICAN RAILWAY ENGINEERING ASSOCIATION COMMITTEE ON SHOPS AND LOCOMOTIVE TERMINALS

SHEET Nº 5

RAILROAD	LOCATION	STALLS		CLASS OF POWER	RADIUS OF TURNTABLE	DISTANCE ℄ TURNTABLE TO ℄ INNER COLUMNS	DISTANCE ℄ INNER COLUMNS TO INSIDE FACE OUTER WALL	TRACK ANGLE	SMOKE JACKS			DOORS			TYPE OF WINDOWS	FRAME WORK	ROOF	FLOOR	FIRE WALLS	TYPE OF HEAT	VENTILATION	ENGINE PITS					DROP PITS (DISTANCE TO ℄ FROM INSIDE OUTER WALL)			MECHANICAL HANDLING DEVICES	SECTION
		NUMBER	LENGTH						TYPE AND SIZE	DISTANCE TO ℄ FROM INSIDE OUTER WALL	CLEARANCE ABOVE T. of R.	TYPE	CLEAR WIDTH	CLEAR HEIGHT								LENGTH	DISTANCE TO ℄ END FROM INNER COLUMN	DISTANCE TO END FROM INSIDE OUTER WALL	MINIMUM DEPTH	THICKNESS OF WALLS	DRIVER	FRONT	TRAILER		
PENN	TYPE "A" STANDARD		116'-7"	All Pennsylvania	50'	135'-9"	115'-10"	7° 30'	None			Swing Wood	15'-3"	17'-4½"	Steel sash	Steel.	Concrete	Concrete	None	Indirect	Pivoted Sash in Clere Story	86'-6"	10'-10½"	19'-3"	2'-6"	2	26'-9"	43'-5"		Crane	
P.M.	PLYMOUTH, MICH.	15	109'-11"	Freight	50'	153'-3"	109'-6"	6°	Asbestos	24'-6"	17'	Swing Wood	15'	17'-6"	Steel Sash.	Wood	1¾" boards	Cinders	13" Brick 7 & 8 Stalls	Direct	Pivoted Sash in Monitor	80'	13'-1"	16'	3'-0"	2'-6"				None	
P.M.	(NEW BUFFALO) DETROIT, MICH.	16	101'-0"	Freight	45'-5"	119'-3"	100'-6"	7°	Asbestos	16'-9"	16'-8"	Swing Wood	13'-6"	17'-6"	Wood Sash	Wood	Wood	Cinders	13" Brick 8 & 9 Stalls	Direct	Pivoted Sash	76'	12'-3"	12'	3'-6"	2'-5				None	
P.&R.	(ERIE AVE.) PHILADELPHIA, PA.	16	109'-11"	Freight Passenger Switching	50'	120'	109'-9½"	6° 55' 23"	Cast Iron Telescopic	17'-9"		Wood Rolling Wood	13'-6"	16'-3"	Steel Sash	Concrete	Concrete & Tile	Concrete	None	Indirect	Pivoted Sash	71'-0"	11'-6"	10'-3"	2'-9"	1'-6"	40'-6"		65'-2"	Jib Cranes	
P.&R.	RUTHERFORD, PA.	19	78'-3"	Freight Passenger Switching	50'	85'	77'-6"	9° 27'	Cast Iron	15'-6"	15'-0"	Swing Wood	12'-10"	16	Wood Sash	Wood	1x6" Boards	2" Wood on Cinders	None	Indirect	Pivoted Sash	58'	10'-6"	9'-6"	2'-9"	1'-6"	33'-0"		45'-0"	Jib Cranes	
P.&L.E.	HAZELTON, O.	24	101'-6"	Mikado & Smaller	45'	93'-5"	101'-0"	9°	Wood	90'	16'	Rolling Steel	13'	17'		Steel	Gypsum	Concrete	None	Stoves	Ventilators	70'	17'-7"	13'	2'-7"	3'-3"	40'-10"	84'-10"		None	
S.L. & S.F.	AFTON, OKLA.	12	109'-2"	Santa Fe.		154'-5"	108'-9"		Wood	26'-6"	16'-8"	Bi Fold	15'-2	17'	Wood Sash	Wood	Wood	Wood block	None	Direct	Pivoted Sash	80'	9'-0"	19'-7"	2'-9"	2'-9"				None	
S.P.	TRACY, CAL.	9	92'-10"	Mallet		130'	92'-7"	6° 22'	Asbestos	21'-0"	17'-4"	Swing Wood	13'-6	17'	Wood Sash	Concrete	Concrete	Brick	None	None	Sash in Clere Story	74'	4'	14'-6"	3'	2'-3"	38'	29'		None	
SOU.	POMONA, N.C.	18	99'-5"	Santa Fe & Smaller	50'	135'-4"	99'-3"	5° 43'	Cast Iron	19'-1"	16'-3"	Swing Wood	12'-6"	17'	Steel Sash	Concrete	Concrete & Tile	Wood block on Conc. base	None	Indirect	Monitors Louvres Pivoted Sash	70'	16'-6"	13'-0"	2'-10"	2'-6"	47'-0"	46'-7"		None	
U.P.	COUNCIL BLUFFS	40	96'	Mikado Mallet	46'	145'-10"	95'-3"	6° 21' 34"	Asbestos	29'-9"	17'	Swing Wood	15'-3"	18'	Steel Sash	Wood	2x6 boards	Mastic on Conc. Base	None	Direct	Pivoted Sash	81'	6'-0"	9'-6"	2'-2"	2'	59'-6"	47'-6"		None	

Appendix C

ENGINE HOUSE AND POWER PLANTS AND SHOP EXTENSION, COLLABORATING WITH DIVISION V—MECHANICAL

Engine Terminal Layouts

E. M. HAAS, *Chairman;*
R. J. HAMMOND,
G. W. HARRIS,
A. M. ZABRISKIE,
Sub-Committee.

Your Committee has made a very careful study of the subject assigned to it, and presents this report, together with a plan of a typical engine terminal for a thirty-stall engine house, indicating how it may be enlarged for the future, and suggesting that by a simple process of elimination, the terminal may be built for a twenty-stall or a ten-stall house.

Your Committee also appreciates that in many localities it would be impossible to build the typical terminal but it is of the opinion that the general arrangement particularly as regards the facilities and their sequence and spacing may be incorporated in most terminal layouts. Surely there will be a difference of opinion regarding the sequence but your Committee has followed, as near as it could, the generally accepted practice as a guide.

Finally, your Committee believes that laying out a terminal should not be by rule of thumb or by any cut and dried process but each situation needs special study.

First, topographical conditions will affect the scheme as will weather, class of power cleared, time of arrival and departure and future possibilities with respect to the division and system. Studies along broad lines should be made before a layout best suited to meet present and future demands can be adopted.

General

Your Committee has found that in general engine terminal development has lagged behind that of rolling stock, and has now reached a point where many terminals are inadequate and antique in so far as they are adapted to modern power. Investigation will frequently reveal that the reduction in time required for turning power at modernized terminals will be equivalent to adding power to the division. At least, the time saved at any terminal makes possible more revenue service than when the average time of turning locomotives is an hour or two longer.

General Assumptions

Your Committee arrived at the typical layout after making certain assumptions. It had in mind peak conditions in what is known as the dense traffic district embraced in the territory east of the Mississippi and north of the Ohio and Potomac Rivers.

Your Committee is of the opinion that if the terminal could be made adequate and efficient under the conditions prevailing in this district, it would certainly meet the demands of the outlying territory where a much lower traffic density prevails.

It has also been found that in a number of instances, the recommendations which would be made for the district mentioned, would not serve in every particular on the lines south of the Ohio River, west of the Mississippi River and north of the Canadian line.

In some cases, as in the South, the weather is not severe, but in Canada, weather conditions have to be taken into account more than they do at the terminals in the district being considered.

In the West, engine divisions are longer and many other conditions need special consideration before a typical layout can be made. However, your Committee believes that regardless of conditions in the outlying territories mentioned, if traffic density were sufficient, the typical terminal layout would function under the severest weather and traffic conditions.

The typical engine terminal is considered as a division clearing house and it is assumed that it literally controls the amount of freight and passenger service that can be furnished by the Transportation Department. Locomotive statistics show that about as much time is spent by power at the terminals as on the road. Therefore, it is assumed that any reduction in the time required to clear the power at a terminal represents just that much more time that power will be available for road service. Frequently it is found that the facilities provided at a terminal which will save time in turning power, actually cost more to operate than the old equipment or facility that it replaces. When the time saved is considered in terms of the value of power in road service, it frequently will be found that the increased net revenue to be gained more than offsets the greater cost of operating the facilities.

Specific Assumptions

In arriving at the typical layout, the following assumptions controlled your Committee's decision affecting the terminal layout:

(a) This is a division terminal not served by a back shop, but only where running repairs are made to about 150 locomotives daily.

(b) The terminal is situated near the throat of a freight yard and at a point near where power is released or returned to road service.

(c) In selecting a site, it is assumed that the terminal is within walking distance or at least a street car ride of an adequate supply of labor.

(d) Site to be selected after investigating the cost of real estate, restrictions by municipalities, ease of drainage, amount of grading and proximity of ample water supply. (While the cost of real estate for a terminal site must always be considered, it should not be a controlling factor. Occasionally, it will be found that a high priced terminal site will be more than offset by the reduced operating charges incident to a terminal properly located.)

(e) Trackage and other facilities are arranged, having in mind that the terminal will be called upon to clear from four to five locomotives per stall per day, and that the power may arrive in fleets at certain periods.

(f) It is assumed that in addition to the road power (passenger and freight) this terminal also serves a number of switching engines. These are to be stored in the engine storage yard and have access without material interference with the road power, to the coaling station, water and ash handling facilities when in yard service, or may reach these facilities from the engine storage yard before being restored to service.

(g) No attempt has been made to fix the lengths of the inspection and ash pits, the capacity of the coaling station, the lengths of the turntable, the depth of the house, as these are subjects being handled by another sub-committee. If dimensions are shown, they are not recommended.

(h) Provision has been made for expanding the terminal capacity 100 per cent. by adding to all facilities and by providing a second 30-stall house and a second turntable. The additional trackage for the expanded terminal has been indicated. It is also assumed that the importance of the expanded terminal may warrant providing a back shop for general overhauling. The need for this, however, will depend on the location of the terminal with respect to a main locomotive repair plant.

(i) The layout committee has been governed by the principle that it is not enough for an engine terminal layout and facilities to meet the normal demands, but if properly designed, it will function under the severest traffic and weather conditions.

Features of Layout

Entrance to Terminal

Your Committee has endeavored, in making the track layout to group switches so that they may be handled by the minimum number of switchmen, or at towers. At a busy terminal, an interlocking tower is to be recommended at the entrance to the yard. Since it is assumed that most power is released and restored to service at what we are terming the left end of the yard, the main leads to the terminal and from the engine storage yard, are shown at that end. Entrance to the terminal is by way of two leads from the main tracks and a run-around which extends the full length of the terminal yard. Actual connection with the mains will necessarily depend on local conditions and they are not shown but they should be planned with minimum curvature and not more than one back-up movement. While most engine terminals are situated on one side of the main tracks, a desirable arrangement is to split the main tracks and locate the freight yards and locomotive terminal between them.

Wash Platform and Inspection Pit

It will be noted that two tracks pass over the wash platform and covered inspection pits, and track space for twice their capacity has been allowed for waiting power in advance of these facilities. It will also be noted that one track serves as a run-around for switchers which do not need inspection, but need to take coal, water, and sand, and have their fires cleaned. The wash platform and the inspection pit are placed at this point so that the roundhouse foreman may be forewarned regarding repairs to be made. Engine crews also are separated from the terminal force. The wash platform contemplates the use of the spray system of cleaning to facilitate inspection.

Inspectors' and Dispatchers' Office Buildings

It also seems logical to make inspection at the point where the crews are released and good practice from an operating and engineering standpoint to provide a service building for incoming and outgoing crews as well as the engine dispatcher and inspectors at this point. In case the inspection pit is situated near the engine house or the terminal is small, it is good practice to combine the engine crews service building with the machine shop. It may be desirable also in the smaller terminals to have inspectors make very light repairs, testing and tightening.

In this layout, it is assumed that power is released at the inspection pit and a building is provided nearby which serves as an office for inspectors and a locker, tool and toilet rooms for the crews. A pneumatic tube preferably installed overhead should connect the inspectors, and engine house foreman's office for the transmission of reports.

The engine dispatcher is also located in this building which is near the two outbound tracks and close to the engine storage yard.

Cinder Pits

There is some difference of opinion regarding the relative locations of the coaling station and ash pit. Your Committee has studied this and believes that for the territory being considered, it would be better practice to put the ash pit within 800 ft. of the engine house or, at least, no farther from it than it is safe to run an engine without fire on the grates.

The cinder pit has been placed in advance of the coaling station for the following reasons:

(a) Fire cleaning is easier to accomplish on some types of power when the tender is not filled with coal.

(b) Stoker fired locomotives needing inspection or repairs do not take on coal on entering the engine house, but should have it promptly after leaving.

(c) The engine house foreman has time to advise the hostler if he wants an empty tender when the engine enters the house.

(d) The coaling station requires a great deal of supervision, therefore it was considered safer and better to place it in advance of the cinder pit. About 500 ft. of track has been allowed between the inspection and the cinder pits, inasmuch as the latter is the controlling point for power passing through the terminal yard. Crossovers have been provided at this point so that incoming power would have both tracks available for cleaning fires regardless of which track it passed over the inspection pits.

Two tracks pass over the cinder pit, and it is assumed in this case that a water type pit has been installed and that each track is of sufficient length to accommodate at least four locomotives. (A study of cinder pits is being made by another Sub-Committee.) One of these tracks is connected by crossovers to the run-around and the outbound engine tracks, so that a switcher may be restored to yard service without passing over the turntable. If it is desired to clean pans on outbound power a 20 ft. section of the main ash pit may be extended under one outbound track. This may be sloped so that the cinders can be flushed into the main pit.

It is considered desirable and good practice to place a set of blow-off boxes about 100 ft. in advance of the cinder pit, in order that the sludge may be removed from the locomotive boilers before entering the roundhouse. This arrangement greatly reduces the chances of clogging the blow-off line in the roundhouse, and where boiler washing plants are installed gives cleaner water for washing use and less sediment to dispose of.

If a depressed track or a Robertson type cinder pit is used, the space between the outbound engine storage yard and the run-around tracks is sufficient to install two engine tracks with a cinder car track between them without further re-arrangement of the yard tracks.

Coaling Station

The next in order is the coaling station with approximately 100 ft. of engine storage space between it and the cinder pit. This was considered enough because most power is now coaling outbound. The sand tower has been placed in advance of the coaling station a sufficient distance to permit power to take sand without interfering with following locomotives taking coal. The coaling station for the terminal as designed, serves the two inbound and the two outbound tracks. The track hopper as well as the coal supply tracks have been placed in their permanent location. The enlarged coaling station serving four more tracks in the expanded terminal is also shown.

In case it is assumed that the maximum terminal development will require only thirty stalls, or as would be the case for some locations a full circle house is desirable, the track hopper for the coaling station should be placed on the run-around track now shown. The new run-around may be placed just outside this coal supply track and the latter may be inclined so that the cars may be fed to the hopper either towards the engine house or away from it.

Space is indicated for ground storage of emergency coal. Unloading and reloading this may be done from either of the two tracks shown.

Inbound and outbound coal to the coaling station passes over the tracks so indicated. Storage space for fifty cars on the inbound, twenty cars on the incline leading to the track hopper and fifty empties on the outbound track appears to be ample for this terminal. In the case of roads using oil as a fuel the emergency storage space for coal may be used for the oil storage tanks.

Sand Storage

The sand storage bins and dryer are shown beside the coaling station and are served by the run-around track leading from the entrance to the yards. Sand storage for at least four or five months requirements should be provided at this point. The location of this facility contemplates a separate attendant and if possible the track should be elevated over the bins. For terminals serving under one hundred engines, the sand handling plant may be combined with coaling station so one man could attend both.

From the coaling station two tracks lead to the turntable and the engine house with a branch from one passing around the table. A slip switch and crossover at this point permits an engine to move to the outbound terminal tracks without passing over the turntable. A stub-end cinder car track with capacity for ten cars is shown beside the cinder pits, and it is arranged so that loads or empties may be switched from or to the run-around tracks.

Outbound Trackage

After power has been turned, it may be placed in the engine storage yards which are reached by two tracks leading from the turntable. One track passes beneath the coaling station and the other beside it so that power may be coaled outbound. Three tracks lead from the turntable in the opposite direction; one is intended for inbound movements and the other two for outbound power and storage at the house end of the terminal.

Engine Storage Yards

Two separate engine storage yards, one for each engine house, having capacity for at least 20 engines each are indicated on each side of the terminal. Each track holds six locomotives thus reducing switching at this point to a reasonable minimum in order to put any stored engine in service.

Water Facilities

Water columns at points of arrival and departure of power are arranged so that an engine taking water will not block the movement of another. Engines entering the terminal and urgently needing water may obtain it at water columns located near the entrances to the terminal yard. Ordinarily water will be taken at the columns in advance of wash platform or on the outbound tracks. Outbound engines may obtain a full tank of water at the column at the outlet to the engine storage yards.

If, on leaving the engine house, there is a prompt need for water, the column between the two outbound tracks and 300 ft. from the table, serves that purpose. Water for power, entering or leaving the terminal by way of the right end, is provided by columns near the turntable and at the lead from the main track. In connection with the water supply, it is contemplated that the pump will be located in the power house and the two tanks at two points on each end of the system.

Tank storage for about twenty-four hours' supply to carry through in case of break down should be provided. Observation has been that at the average terminal, the reserve water storage is usually too small.

Turntable

Track approaches to the turntable should include at least two from the terminal yard side and two which can be used to approach and leave the table from the side away from the yard. At a busy terminal two approach tracks and two tracks leaving the table, making four in all, are recommended. It is also desirable from an operating standpoint to have all approach tracks line up with those leading into the house.

While the size of the turntable is a matter for the consideration of another committee, it has a material bearing on the number of stalls possible in a house without requiring frogs in the track at the edge of the table. Generally speaking, the longer the table, the less waste floor space at the rear of the house. This is true because it is possible to reduce the stall angle.

Engine House

The engine house has been located at a sufficient distance from the terminal yard runaround track to permit straight track leads from the coaling station to the light repair shed which may be considered as a means of future expansion. The first section to be constructed is also placed so that the circle may be completed or a second house and table provided as a future development.

Your Committee has found quite a divergence of opinion on the location of the engine house proper and believes that it will be out of the question to reconcile this.

On some roads, particularly those in the West, where they have long divisions, it is necessary to place every locomotive in the engine house before restoring them to service. One stall to two or three locomotives for a twenty-four-hour period is all that is required, consequently a full circle house may be operated over one table. In the congested district your Committee finds that preferably thirty and not to exceed forty stalls should be operated over one table, and particularly at terminals where four or five locomotives per stall are handled in a twenty-four-hour period. From the foregoing it will be seen that in the case of one terminal, provision will have to be made for completing the full circle, whereas, at the other, provision need not be made for more than forty stalls to the circle. In either case, your Committee would recommend track approaches from opposite sides of the table and approaches so arranged that one track will line across the turntable with one in the house. This will permit a dead locomotive to be placed in the house without difficulty. Preferably this track should be one that leads through the engine house into the machine shop. The type of engine house, engine house equipment and recommended construction are being handled by another committee.

When the terminal is expanded 100 per cent, your Committee believes that the second table and engine house located as shown will best meet operating conditions. Then, too, if conditions like those mentioned as prevailing on Western roads occur the full circle engine house may be developed without difficulty. In case two tables are installed, a section of track with crossing frogs connecting the tables will be found useful.

Machine Shop

The machine shop is considered both as an independent working unit as well as an essential part of the engine house proper. Wheeling and unwheeling and other repair work requiring the attention of skilled workmen might properly be handled in the machine shop. In any event the drop pits should be near the entrance to the machine shop. In the typical layout, this shop is connected to the engine house on the terminal approach side by a passageway lower than the machine shop building proper, but high enough to clear a locomotive. The purpose of this is to prevent engine house gases entering the machine shop and still have an open passageway between the two. The tool room opening off of this passageway makes it convenient to both the engine house and machine shop. The foreman's office is also shown on the passageway and near the engine lead and departure tracks where he can observe movements at the turntable and at the same time be convenient to the engine house and machine shop. A small blacksmith shop is shown in the corner of the machine shop close to the engine house so that it may serve both.

As an alternate, another satisfactory machine shop layout is shown. This, it will be noted, occupies a part of the engine house circle and puts the drop pits in the machine shop proper.

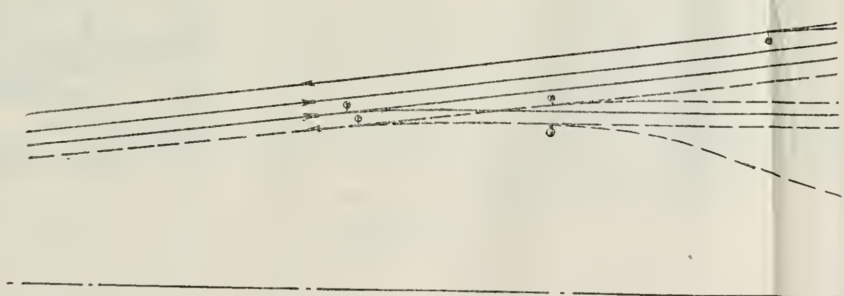
Light Repair Shed

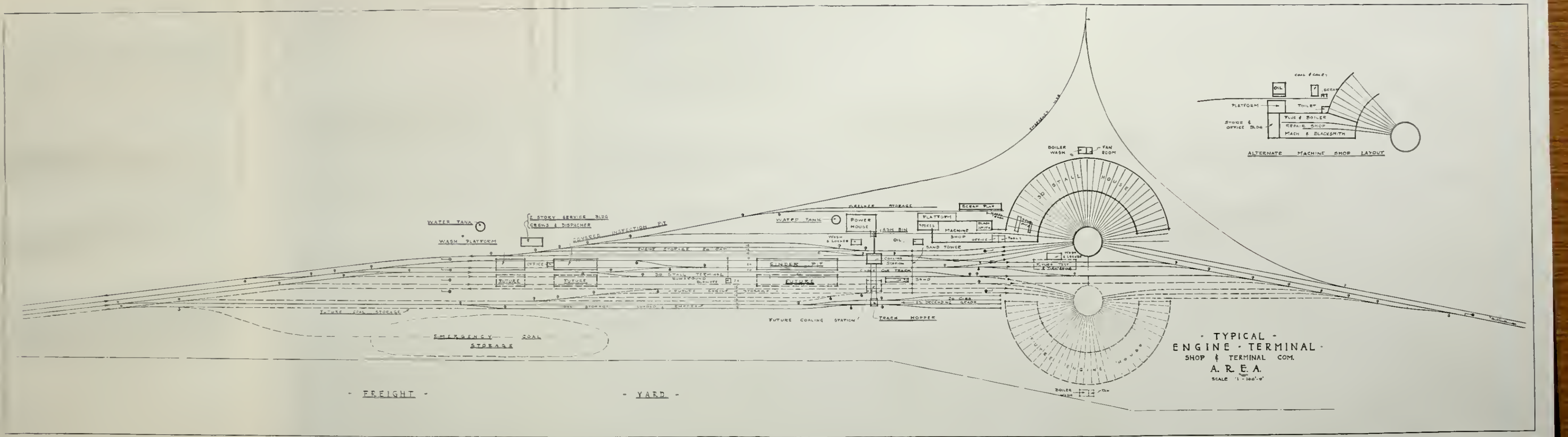
While the light repair or tightening and test shed has been employed by a number of roads for many years and has demonstrated its economy, it is not in general use throughout the country. Your Committee believes that it is to be recommended at terminals turning one hundred or more locomotives. It provides cheap floor space for tightening and testing, thus reserving the higher priced floor space in the engine house proper for heavier running repairs.

It has been found that at some terminals, as many as sixty per cent of the locomotives handled never have occasion to go into the engine house. This shed may be of reinforced concrete or heavy timber construction. It should preferably be located near the machine shop where parts are available and supervision made easy.

Store House

The store house has been placed so that it is convenient to the engine house and machine shop, where the call for supplies will be greatest. A liberal outside platform with ramps leading to the engine house and yard and a track on which material may be delivered in carloads covers the essential requirements. Permanent walks and drives between the various facilities and the store house are very essential to economical handling of materials. A scrap platform on the store house track, but near the points where scrap accumulates, is also shown. The through wheel track contemplates the delivery of good wheels and storage space for bad orders.





ALTERNATE MACHINE SHOP LAYOUT
OIL
PLATFORM
TOILET
FLUE & BOILER
REPAIR SHOP
MACH & BLACKSMITH
STORE & OFFICE BLDG
BOILER WASH
FAN ROOM
STALL HOUSE
WATER TANK
WASH PLATFORM
2 STORY SERVICE BLDG
CREWS & DISPACHER
COVERED INSPECTION PIT
POWER HOUSE
ASH BIN
PLATFORM
MACHINE SHOP
SCRAP PLAT
OIL
SAND TOWER
OFFICE
CINDER PIT
FUTURE
COALING STATION
TRACK HOPPER
FUTURE COALING STATION
FUTURE COAL STORAGE
EMERGENCY COAL STORAGE
FUTURE ENGINE HOUSE
- TYPICAL -
ENGINE - TERMINAL -
SHOP & TERMINAL COM.
A. R. E. A.
- FREIGHT -
- YARD -

Oil and Lantern House

Oil requirements at the terminal calling for thirtry stalls averaging, say, four engines per stall for a 24-hour period, are so great that a separate oil house with an attendant located at a point convenient to the engine house and machine shop is recommended. At a terminal where the oil requirements are light, this oil house may be made a part of the store house, but separated from it by fire walls.

Power House

The power house is central with the 30-stall terminal requirements as well as for the future development. It has to be located near the coaling station so that one track hopper, elevating and conveying equipment can deliver coal to both. This also saves switching coal to two points. An overhead ash hopper and bins are shown over the track which passes through the machine shop.

Underground concrete pipe ducts from the power house to the various buildings are contemplated for the installation of steam, hot water and air.

Boiler Wash and Fan Room

The boiler washing plant which has become an essential part of engine terminal equipment in bad water districts, together with a fan room having in mind a hot blast heating system, are installed in the same building, but separated from the engine house. This is done to place both of these facilities central with the engine house or where the maximum demand for hot air and hot water occurs. The building is placed at least fifteen feet away from the back of the engine house proper so that it will not obstruct daylight in the rear of the stalls at this point.

Wash and Locker Facilities

A separate wash and locker building for the terminal repair force is provided at a central point. These facilities for the crews are provided in the office and locker building beside all inspection pits.

Conclusions

Your Committee, in its study of this subject, has agreed that there are so many special considerations on an engine terminal layout, that it is impossible to lay out anything but a typical one, showing a desirable arrangement and sequence of facilities. It, therefore, presents this as a progress report for your information and asks for definite suggestions and criticisms. With these and several other typical layouts, providing for certain conditions, a final report on this branch of the subject should be possible next year.

Appendix D

DESIGN OF CAR SHOPS

Report on Passenger Car Repair Shops

L. K. Sillcox, *Chairman;*
Walter Goldstraw,
E. M. Haas,
L. L. Tallyn,
A. M. Zabriskie,
Sub-Committee.

So many passenger car repair shops throughout the country today have a fifty-year old nucleus, with piece-meal additions, in which the shopmen are making the most of what their shops possess, and are struggling along as best they can to keep modern equipment in repair and serviceable, that it seems proper that careful study and consideration be given to the subject of repair shops, with the view of improving facilities and developing plants that are as modern as the equipment to be maintained. If each workman in a shop, where 1,000 men are employed, saved five cents for the railroad company each day, the sum saved in one year, of 300 working days, would amount to $15,000.00, an amount which is equivalent to five per cent interest on a capital of $300,000.00. Yet in most, if not all, railroad shops it is indeed conservative to estimate that each man wastes five cents worth of his time daily due to poor shop layouts, poor arrangement of facilities, antiquated tools and machinery, or old-fashioned methods of handling work, conditions over which neither he nor his immediate supervisors have any control.

Harrington Emerson, in his book, "The Twelve Principles of Efficiency," says "The railroad that dispatches its 'crack' trains with ninety-nine per cent of time accuracy has either no dispatch system or a very crude one for work, either big or small, through its shop; therefore, in some cases it fails to realize an efficiency of even one per cent, and on the big average of all shop work fails to realize either a time or cost efficiency of more than forty per cent. * * *

"It is interesting to note in the matter of repairs the great superiority of marine repair dispatching over locomotive repair dispatching. A vessel will be put in dry dock * * *, and be completely scrapped, repainted, new propeller and rudder fitted, new plates inserted, in perhaps three days. * * *

"A fifteen-day schedule for general repairs to a locomotive is considered fast time and the average is nearly thirty, but if the time for each item is separately entered in the summary, it is hard to discover why three days would not be enough."

Considering the importance of these facts, this report is written with an object to obtaining high efficiency fully as much as to gain mechanical excellence. However, the two are co-ordinate, for high efficiency bears with it mechanical perfection.

In laying out a passenger car shop, or any other, no better advice can be given than that offered by Herbert Kaufmann, when he said, "Make your chart before you start. Know what you're after before you start out for it."

Your Committee in submitting this report has endeavored to cover only what seems to be best in layouts and treat the subject so that it will be of most assistance to the greatest number. Most railroad shops of today are operated on the hourly basis, and it is therefore on arrangement, organization and supervision that efficiency, output and workmanship depend. Furthermore, when it is remembered that organization and supervision are in a large measure dependent on layout of plant and facilities the importance of the first factor is appreciated.

The shop, yards, buildings, and machinery should be arranged so that the various operations follow through in a logical sequence; the bad order equipment should pass in at one point, progress by various steps, without hindrance, or delay from congestion or awkward movements, over a predetermined circuit to the point of release and emerge as a finished product. In general repair work, a car will enter the shop, be unwheeled and stripped, after which the car, trucks and trimmings will progress through the shops, each over a different route, and will finally meet at some point for trimming, assembly and release.

The older shops are generally situated within the limits of some city, with the result that now the cities have grown around them, hemming them in and forbidding their further development. It is hopeless to attempt the development of a modern plant in cramped quarters. Therefore, a location must be sought elsewhere even though the shop crews are well established and the labor conditions favorable at the old point, but in the selection of the new site, while it may be true that labor will follow the job, the importance of selecting a location with a suitable labor market must not be neglected.

Topographic and climatic conditions must not be lost sight of, and in laying out a plant, nature must not be forgotten. A careful study of the forces of nature must be made so as to offset or reduce any hindrance from this source and at the same time secure any benefits that may be derived. Too often, in order to take advantage of cheap real estate, ease and simplicity in providing drainage and other things, shops are located in valleys adjacent to water courses which cannot be controlled, with the consequence of much damage from floors and severe losses from delay and interruptions to operations, the cost of which offsets the savings in first cost many times over.

It is useless to attempt, in an ideal layout, to fix definite dimensions and proportions. These must be left to be determined for each particular case from the policies, practices, and conditions prevailing. It is the policy with some railroads to thoroughly overhaul the trucks of every car passing through the shops; therefore, for them an elaborate truck repair shop is required. At other shops a large portion, or all of the equipment may be steel cars requiring extensive steel working machinery and but small wood mill equipment. Roads, not operating their own sleeping cars, do not require the space for upholstery work demanded by those that do. Where the climate is mild a great deal of work may be done out of doors, and so there are a great many factors to be considered.

It is our object to offer something that can be used as a guide. The Committee's submission, therefore, is laid out so that all operations can be taken care of indoors and those using it as a guide need subtract rather than extend.

All buildings should be substantially built, of fireproof construction, well lighted, comfortably heated, and have good ventilation. The last three requirements, together with large sanitary lockers, wash and toilet rooms, go a long way in keeping up the morale of the employes and will produce returns on investment in the form of efficiency, quality and quantity of the work produced. .

For the passenger car work, buildings with transverse tracks served by transfer tables undoubtedly give the best operation. Passenger coaches, which are handled singly, can be placed or shifted about must more expeditiously and with better provision in a transverse layout than in any other. Frequently, the Transportation Department requests that preference be given certain cars after they have been placed in the shops, making it necessary to shift their position. The plant should, therefore, be flexible for the moving of individual cars. On the other hand, the reverse is true of freight car shops. Freight cars are handled in groups; therefore, a better operation is to be had from a longtitudinal layout.

Your Committee wishes to make the following general comments and recommendations for the various subdivisions which make up a large passenger shop layout.

Coach Paint Shop

The Paint Shop should be of fireproof construction, light, airy, roomy, free from dirt and dust, and should be well heated in cold weather. The most economical operation as to first cost and production is obtained with a building of sufficient width to hold two cars on each transverse track with ample aisle room on either side and in the middle. With more than two cars per track awkward conditions arise in moving the center car. Each track should run through and be served by a transfer table on either side of the building. The tracks should be 25 ft. from center to center. The floor should be concrete and should pitch to floor drains to allow for scrubbings and quick drying after.

Traveling cranes and supply tracks are not needed.

Permanent scaffolds should be provided. They should be adjustable and easily operated, preferably suspended from overhead so they can be pushed up out of the way when not in use.

Ample space should be allotted for storing and mixing paints. This should be located at the center of the building, for so large a plant as this, so as to be equally accessible from the extreme ends of the shop.

Ample toilets, wash and locker rooms should be provided.

Some places may require baking ovens, in which case they may be provided for across the transfer table or a few stalls of the paint shop may be converted for this purpose.

Coach Repair Shop

The same width and track arrangement is recommended as for the paint shop. The building should be divided into two main bays, one on either side with a center aisle about twenty feet wide in which should be installed a fifteen-ton traveling crane. This should be operated from the floor so that the operator can hook on his own loads or do other tasks at such times as the crane is not in use.

The floor should be wood block substantially constructed to withstand the severe wear from the handling of heavy parts.

Permanent scaffolds should be provided of the same constructions as that recommended for the paint shop.

The shop should be piped for compressed air, steam, water, and acetylene, and ample electric connections should be provided.

If cars are all placed on dollies before they are taken to the repair shop, pits are not necessary. However, as the probabilities are that not all cars will be unwheeled, a portion of the stalls should be provided with pits.

Some tools and machinery are necessary in connection with this shop, although it may be the intentions to do the greater portion of the work in the main machine and blacksmith shop; therefore, a certain space should be set aside for this purpose. The pipe shop, air room, and tin shop should be annexed to this building, if possible, as the greater portion of that work comes from and goes back to the cars while in this shop.

As with the paint shop, the best operation will develop from this shop being served on both sides by a transfer table.

Wash House

At most shops the cars are washed on the same track on which they are painted, or on tracks in the paint shop especially set aside for this purpose. At some places the washing and stripping is done on the same tracks. In view of the continual dampness resulting and the hindrance which it produces on the paint work, the Committee recommends that a separate department be assigned and be properly equipped for this work. Certain stripping such as the removal of air equipment can be advantageously taken off here.

The wash house should be well lighted, heated and ventilated so the cars will dry quickly. It should have a concrete floor, properly pitched, with frequent floor drains to give good drainage. Gutters in the floor between tracks or so located as to catch the drip from the sides of the car will greatly assist in keeping the floor dry.

Scaffolds should also be provided and the shop should have water and steam connections.

Floor space should be provided in a convenient location for the preparation of soap and acid solutions.

Stripping and Trimming Shop

A very logical and economical grouping of operations can be accomplished by providing a place for stripping cars of sash, doors, upholstery, and fixtures as they pass into the shops and another for trimming them as they go out with space in between where the parts removed can be repaired, finished, and stored ready to be placed back on the car as it goes out. It is the custom at most shops to remove such things either in the yard, paint or repair shop, haul it to the respective departments for repairs, painting, plating, etc., and then haul it back again to paint shop, yard, or some other place where the car is trimmed, all of which involves considerable labor and forms a serious problem in the shop operation. Therefore, your Committee recommends the adoption of an arrangement as just described and as indicated in the proposed layout for large plants of this kind, where the trim may be removed, pass through its respective department, while the car is progressing through the shop, be stored, finished, and ready for the car after it has passed the paint shop and has been brought back to the trim shop on its way out.

Unwheeling Hoist

The manner of removing trucks from under the coaches varies greatly with different shops. At some shops the car is taken directly to paint shop where the trucks are removed and the body set on horses. The trucks are then taken to the truck shop or machine shop. In some places the trucks are overhauled at one end of the coach repair shop or paint shop, while at others they are taken to a separate shop. At some shops the cars are jacked up in the yards, the bodies put on dollies and the trucks and bodies wheeled to the respective places for repairs.

A much smoother operation is to be had from the practice of placing the bodies on dollies, providing the course through the shops is smooth and systematic. The unwheeling if done by a permanent or fixed hoist can be accomplished more expeditiously and with less hazard to employes than by the use of the ordinary jacks. With a layout of this size the labor saved will more than justify the expense involved. The use of dollies not only affords an easier and more simple way of handling the bodies but in case of fire offers a chance of saving some cars which would be impossible if resting on horses.

In the layout herewith submitted, two traveling cranes, one located in the stripping shop and the other in the trimming shop, are suggested for this purpose. These cranes should be at least of 80-ton capacity and have two hoisting drums, one for either end of the car body.

Truck Shop

In most shops the trucks are repaired on the same tracks with the cars, or on a few designated tracks in the passenger car repair shop. A separate truck shop gives better supervision, more production and permits a better and more extensive use of the proper tools. A separate shop permits the segregation of material, tools, and facilities such as hoists, lye vats, spring testing machines, truck gauges, and templates. The shop tracks should be transverse with room on each track for two sets of trucks. The building should have two main bays on either side and a narrow bay at the center with a ten-ton traveling crane. A longitudinal track should run the full length of the building to facilitate the handling of mounted wheels and axles.

Over each track in the side bays should be installed a five-ton floor controlled traveling crane for the handling of truck parts, and the removing and replacing of wheels.

There should be ample track space outside for the storing of tracks, ready for and after leaving the truck shop. The truck shop should be located closely to the smith, machine and wheel shops. The shop should be well lighted, heated and ventilated. Concrete or wood block is satisfactory for floor.

Wheel and Axle Shop

This shop should be conveniently located to both the freight and passenger repair shops. Large yard space is necessary in connection with this department for the storage of wheels and axles, both mounted and unmounted. Free movement of this operation is essential to economical production and great care should be exercised in laying it out. Monorails form the best method for serving this shop. These should extend out into the yard for the handling of wheels and axles both into and out of the shop.

The building should be well lighted, heated and ventilated, and the floor should be substantially constructed, preferably of wood block.

Blacksmith and Machine Shop

These two shops are treated together because most of the work progresses through the smith shop into the machine shop to be finished. They should be very conveniently located with respect to the truck shop and easily accessible for the coach repair shop, as these two departments furnish practically all the work.

These shops should be well lighted, heated and ventilated. Particular attention should be paid to ventilation in the smith shop.

Wood block floor is preferable for the machine shop, while a good solid dirt floor gives best results for the smith shop.

Yard cranes and push cars are necessary for handling material to and from the shops, and monorails, jibs, etc., should be amply provided for handling the work inside the building.

Wood Mill, Pattern and Cabinet Shops

These three sections are closely related. All do wood work, and in the majority of layouts are combined under one roof and it is proper that they are. The mill should be conveniently located with respect to both passenger and freight car repair shops and should be so placed that ample yard and storage space is available for the storing of lumber. It should have as an accessory a dry kiln and large sheds for the storing of dried lumber.

At least two supply tracks, leading from yards and sheds, should be run longitudinally through the mill and the machines so spaced that heavy timbers can be easily handled from cars to machines and progress through the mill in logical sequence, leaving the mill at the opposite end from yard in a finished state.

The building should have good light, heat and ventilation and should be of fireproof construction.

Some means of disposing of sawdust and shavings must be provided. The preferable means of disposal is to bale for a commercial trade. There is now a good demand for shavings as a substitute for straw in packing crockery, etc. This is preferable to burning them in boilers as they are not satisfactory fuel and in addition require special boiler settings and provisions for handling.

If many patterns are to be made and stored, a separate fireproof storage should be provided.

Power Plant

This involves a study in itself for a great deal can be done toward economy in the selection and proper installation of boilers and appurtenances, together with the proper coal and ash handling equipment. The power plant should be made ample for all requirements, spare units should be installed to insure continuity of service and to allow for the making of routine repairs.

The water, steam, air and electric power systems for a layout of this kind are worthy of very careful study and consideration.

Miscellaneous

(a) Foundry—Unless there is to be a separate foundry run independently to serve all departments, it is well to have a small brass foundry in connection with the Car Department.

(b) Sand Blast House—This because of the dust and dirt produced should be isolated somewhat from the other department, but should not be too far away to cause delay in detouring from the main circuit.

(c) Reclamation Department—Should be centrally located with respect to freight and passenger car repair and machine shops and in the vicinity of the scrap yard.

(d) A fire department, hospital, and ambulance is quite essential with a plant of this size.

(e) All transfer tables should be of ample dimensions and capacity to allow for rapid travel and expeditious handling of cars.

(f) Paved roadways and walks of ample width should be provided throughout the plant to afford ease of communication, facilitate trucking and allow unobstructed passage for both the fire-fighting equipment and for the ambulance.

From the standpoint of economy in layout and subsequent operation, the grouping of as many departments as can be consistently united into one large plant is recommended. Between the Locomotive and Car Departments the storehouse and its supply yards, the power plant, water, heat and light systems, the fire department, hospital and ambulance service, and the general office can be used in common at a lower initial cost outlay than would be necessary to fit up two independent plants. The relation between the Passenger Car and Freight Car Departments is even closer. The wood mill, the machine, blacksmith, and wheel shops can handle work for either equally well. The supplies, stores, power plant, etc., can serve both and the extra land, buildings, and machinery necessary to fit out two separate plants would more than offset any advantages that may be derived from separate operations.

In preparing the layout submitted with this report (see Fig. I) it was assumed that the topography was favorable and that ample property was available. It is considered that the plant as shown is to form a part of a complete repair point for the maintenance of both cars and locomotives; therefore, the power house and Store Department will be common and should form the natural separation between the two departments. In sizes, the intention is that it be sufficiently extensive to take care of most any large point. No provision for extension has been indicated but the suggestion is that if only a portion be used the remaining space be allotted for this purpose or if built full size that additional space transversely be provided.

The actual capacity of the plant as laid out will depend to a great extent on the average painting schedule. The paint shop will hold sixty cars, and if worked on an eight-day schedule, should permit of a capacity of eight cars per day. This operation is really the criterion, and if other departments are properly proportioned, will control the output of the entire plant.

Thus, unimpaired by cramped quarters, it is the intention to execute a layout which will give freedom to productive movement of cars through the shops, eliminate all unnecessary handling of materials and parts and locate the various operations and groups logically and with due regard to their relation to each other.

The routing through the shop forms a complete circuit. The cars to be repaired are delivered to the receiving yard from which place they are switched, as selected, to the tracks leading into the stripping shop. Inside this building brake rods, etc., are disconnected and removed and the car moved up under the crane where the body is removed from the trucks, set on to dollies, and the trucks switched out. The outside track should be used for the handling of trucks, from which they can either be moved via the transfer table or shifted in the opposite direction and placed on storage tracks. Before leaving the stripping shop all the sash, doors, hardware, upholstery, fixtures, etc., are removed and delivered to the proper quarters for repairs.

From this building the car body is moved via transfer tables and tracks, first to the washing shed, then to the coach repair shop and from thence to the paint shop. After the car has been painted it is brought back via transfer tables and tracks to the trimming shop, trimmed, mounted onto its trucks, leveled, brake rods hooked up, and put onto the outgoing tracks for release.

The trucks are removed from the storage tracks, to which they were shifted after the bodies were taken off, via transfer table to the truck shop for repairs, after which they are placed on the storage tracks adjacent to the trim shop to await the arrival of the bodies.

The wheel shop is at one end of truck shop and the smith and machine shop is alongside of it. As the heaviest work contributed to each of these three shops originates in the truck shop, this forms a logical grouping. The coach repair shop located just across the transfer table from the smith and machine shops with the mill just above it forms another convenient grouping.

Between the stripping and trimming shops are located facilities for handling sash, doors, upholstery, fixtures and hardware. Thus the handling of these parts is reduced to a minimum.

The paint shop which is practically independent from the rest of the layout is at the exereme end.

Between the wash house and repair shop is space allowed for air equipment, pipe work, tin shop, and for tools, and such small machines as will be necessary for this department, it being considered that the heavy smith and machine work will be done in the main building.

At the lower end of the wash house is space for the fire department, ambulance, and hospital. This is a convenient point and gives them a central location.

For such cars as are required to have paint burned off and sand blasted a separate building is provided just above the stripping shed. The dust arising from this prompts its being isolated; this location while taking care of this feature does not break up the free movement as the car after being stripped can be moved via transfer table to sand blast house and from thence to repair or paint shop. The back up movement is not a serious obstacle in this case as the percentage is low of the cars that are burned and sanded.

There is ample space and track facilities around the wheel shop for the storage of wheels and axles both mounted or unmounted. The wheel shop is conveniently located with relation to the passenger car truck shop and to the freight car repair plant.

The smith and machine shops are primarily to handle passenger car work only. Ample storage space has been provided for material both raw and finished between the building and the transfer table and between the machine shop and freight car department. Yard cranes are indicated which will greatly facilitate the handling. Standard gauge tracks over which push cars can operate will further assist in this respect. The close grouping of machine, smith, truck and wheel shops will provide for easy supervision forming one very economical feature.

It has been the intention throughout to eliminate all small buildings or sheds. Such structures not only form the nucleus for the addition of other sheds as the plant expands but brings about a bad operation in supervision and produces excess handling of materials and parts.

It is the Committee's recommendation that space inside the main buildings be set aside for toilets, locker rooms, and offices, and thus avoid all leantos and unsymmetrical additions. Toilet and locker rooms can be installed on main floors with offices above very advantageously. An elevated office is desirable as it gives isolation and a good means of supervision.

The reclamation shop has been located between the machine shop and the freight car repair shop. This is both a logical and convenient point as parts to be reclaimed will be received from both plants. The scrap bin should also be placed in this vicinity.

The wood mill, cabinet and pattern shop are logically located between the coach repair and the freight car repair shops, providing free movement for material to either place. The lumber storage is below the coach paint shop and also adjacent to the mill. It is considered that the layout is equally accessible from either end for switching in cars of material.

A "rip" track with drop pit is also suggested, for light work on cars not required to pass through the shop. This has been located near the receiving yard.

Above the passenger car shop a layout has been prepared for a freight car repair plant of considerable size. The cars feed through this shop from the storage yard at upper right, are repaired and pass through to the paint shop. The yard crane at the right end provides a means of dismounting such cars as require truck repairs. The body is to be transferred to rebuilt trucks and passed into the shops for further repairs. A wing has been provided on lower right for smith and machine shop with space for steel frame erecting and truck repairs. The freight car shop proper should be constructed in three main bays with traveling cranes, running longitudinally in each. The frame erecting and truck repair portion should be served with monorails as should also some portions of the smith and machine shop. A storage yard with bridge crane provides ample facilities for storing and handling steel and other materials necessary to this work. For such cars as it is necessary to sand blast a separate building has been provided at the right below the main entrance lead tracks. The stub tracks from the erecting and truck repair shop afford storage for trucks, both bad order and rebuilt. The building will hold from 100 to 110 freight cars.

The space allotted to machine and erecting shop will have to be enlarged if this shop is to be used exclusively for repairing all steel cars. The proportions as here laid out are for the general run of work ranging from heavy steel underframes to the lighter construction with wooden sills.

At the right end of the layout there is provided ample track storage for bad equipment. While it may appear large, it is not out of proportion with the volume of work that can be handled at a plant of this size, and the flexibility thus provided will add greatly to the efficiency of its operation. If so desired, there is space that may be devoted to outside repair work. Furthermore, the layout, capacity and operation of this yard will depend greatly upon local conditions, position of main lines and other controlling features.

It is considered that the layouts and comments on the special features of some existing plants will be interesting and instructive in connection with this study. We are, therefore, giving some information that we have been able to gather during the past season.

A. T. & S. F. Shops at Topeka, Kan. (Fig. II)

This shop turns out from 50 to 55 general repairs per month with about 450 men. There are three coach paint shops and one coach repair shop in a transverse layout served by transfer tables, constituting a part of a large central plant where repairs are given to all classes of equipment. The coach repair department is confined between the locomotive roundhouse and terminals on one side and the locomotive repair shops on the other, and is separated from the freight car repair plant by the locomotive shops. The passenger car plant has its own smith and machine shop, mill, etc., and is quite independent of the other departments. All work is done inside the buildings.

The cars are stripped, washed, and the paint burned off, if necessary, on tracks assigned for that purpose in paint shop No. 3, after which they are moved to the repair shop where the trucks are removed. Trucks are repaired and returned, and the car retrucked before it is moved to the paint shop.

C. & N. W. Shops at Chicago (Fig. III)

This plant has a monthly output of about 150 general repairs with around 570 men, exclusive of mill, cabinet, and blacksmith shop. There are three coach repair shops and one large paint shop in a transverse layout served by transfer tables.

Cars are stripped in paint shop, taken into yard and dusted by air, removed to coach repair shop, washed and repaired and then moved to the paint shop where they are painted and trimmed. The trucks are repaired on four designated tracks in the coach repair shop.

The freight car shop and repair tracks are adjacent to the passenger car plant and the machine and smith shop, and other facilities are used jointly.

C. B. & Q. Shops at Aurora, Ill. (Fig. IV)

The monthly output of this plant in normal times is 40 to 45 general repairs with about 250 men. The Locomotive Department is at one end of the layout with the freight car repair department at the other. The coach repair shop is 310 ft. wide with transverse tracks holding three large cars each. In the paint shop four tracks are separated from main shop by a wall and used for washing cars. The floor in washing shop is of concrete with gutters for drainage. The sash varnish room and upholstery shop is on second floor over the wash tracks. At the south end of the coach repair shop fixed air cylinder hoists are installed for removing bodies from the trucks. The car bodies are placed on dollies for moving about the plant.

The car body is removed from the trucks, by the air jacks in the yard, taken to the wash tracks in paint shop, stripped and washed. It is then moved to repair shop, repaired and from there to paint shop where it is painted and trimmed. The trucks are repaired on four designated tracks in the repair shop.

C. & A. Shops at Bloomington, Ill. (Fig. V)

In normal times the monthly output of this shop is twelve general repairs with about 150 men. The coach repair and coach paint shops face each other with a transfer table between, and the other departments are grouped in smaller buildings around these two main shops. The passenger car plant is hemmed in on three sides by the freight department and on the fourth by the locomotive shops.

Steel freight repairs are taken care of in a transverse repair shop served by a transfer table.

In the coach repair shop, which has ten tracks, two tracks are used exclusively for truck repairs, one of which has a pit and overhead crane. The upholstery is stripped from the car in the yard on a track alongside the upholstering shop. Permanent air jacks are provided along this track with which to remove the car bodies from their trucks and place them on dollies. The sash, doors, and other trim are removed from the cars, after they have been placed in the coach paint shop. The car is also washed at this point, and the paint burned off, if necessary. The car then moves to the coach repair shop for necessary repairs and is moved back into the paint shop for painting and trimming.

C. & E. I. Shops at Danville, Ill. (Fig. VI)

The monthly output of this plant in normal times is seven general repairs and about ten light repairs with around 100 men employed.

The general work is all carried on in one coach shop, which is served by a transfer table used jointly by the Car and Locomotive Departments. Wood, mill, wheel shop and blacksmith shop are used jointly with the passenger and freight car departments, and the machine shop serves both the Locomotive and Car Departments. The main coach repair shop is divided into five sections separated by walls, five tracks being used for painting cars, thirteen for coach repairs and truckwork, and three for miscellaneous work. Cars are stripped and washed on tracks in the paint shop, after which they are moved to the repair tracks for general repairs and returned to the paint shop for painting and trimming.

C. P. R. Angus Shops at Montreal, P. Q. (Fig. VII)

The passenger car shops have a capacity of about 130 cars and the monthly output is 225 cars, including both general and light repairs. The shopping schedule requires that the cars must go through the shops at least once a year. Heavy repairs are usually given each alternate year.

There are four passenger car shops, two on each side of one long transfer table. Upholstery, lamps, and fixtures are stripped from the cars in the yards, at the east end of the tansfer table and removed to the upholstering shop close by. The car is then moved to tracks set aside at the east end of the north coach shop where they are washed and the sash and doors removed. If necessary, the paint is burned off at this point. The car then enters one of the four coach shops where it is repaired and painted. When there is heavy steel work to be done on a passenger car, it is usually repaired in the steel freight car shop and then removed to the coach shops for painting and finishing.

The stub tracks, which are provided between the main tranverse tracks, leading into the coach shop, are provided with the steam connections so that the cars can be shunted on to them and the interior work carried on out of doors, when the shop is crowded for work.

With the four coach shops which contain over 100 shop tracks and the large number of stub tracks provided, an enormous output of cars can be obtained. Throughout the various shops numerous small stockrooms are provided for taking care of the smaller stock material. This feature eliminates a great loss of time which otherwise would be consumed in making special trips to the main storehouse for such material.

C. C. C. & St. L. Shops at Beech Grove, Ind. (Fig. VIII)

This is a comparatively new plant and it has never been operated to 100 per cent. output. In normal times about 300 men are employed on passenger car work. There are 24 tracks in the coach repair shop and 22 in the paint shop. Each of these tracks will hold two cars.

The passenger car and locomotive shops are united into one large plant. The coach repair and paint shops lie opposite each other with one transfer table between serving the two. The coach repair shop is divided into two main bays with aisles on either side and at the center, wherein are installed traveling cranes to facilitate the removal of trucks. and the handling of material.

Truck repairs are taken care of at the end of the coach repair shops next to the storage yard and tin smith, steam fitting, upholstery, and electrical work is done at the opposite end.

Checkered steel plate is used for floor in the portion devoted to truck work and an overhead traveling crane is installed to facilitate the work.

Along the north end of locomotive and car shop buildings is a storage yard served by an overhead crane. Beyond this yard and opposite the coach shops is the wood mill with the freight car repair plant back of it. Across the storage yard and opposite the locomotive shops are the power plant and the general stores.

Back of the storehouse to the west of the freight car shop is a large car wheel shop with plenty of yard room and ample facilities for handling work.

The car is first taken to the paint shop where it is stripped and washed and then moved to the coach repair shop where trucks are removed. After body and trucks have been repaired the car is again moved to paint shop for painting and trimming.

C. M. & St. P. Shops at Milwaukee, Wis. (Fig. IX)

The monthly output from this plant normally is about 56 general and 15 light repairs with 700 men exclusively on passenger car work.

These shops form a part of a large plant where repairs to all classes of equipment are made and where a larger amount of manufacturing is done.

The passenger car department consists of two main coach repair and paint shops with a miscellaneous shop between, a truck shop and two blacksmith and machine shops. It is a transverse track layout with the buildings in column formation served by two transfer tables, one of which serves both the truck and the old paint shop.

The plating department is on second floor at the east end of the new coach shop. In the miscellaneous shop are the offices, upholstery, paint-mixing and storage, tin shop, etc. The mill cabinet and pattern is in a separate building lying to the east. At the east ends of truck shop and both smith and machine shop buildings are wheel and axle shops The coach wheel work is done in the truck shop. The west end of truck shop is devoted to locomotive tender repairs. Between the two smith and machine shops there was formerly a steel freight car shop which was burned down about a year ago and has not yet been rebuilt. The blacksmith and machine shops are used jointly by passenger and freight car departments.

Cars are taken direct to one or the other of the coach shops where trucks are removed, bodies stripped, washed, repaired, painted and trimmed, and remounted on the trucks after they have been repaired and returned.

G. N. Jackson St. Shops at St. Paul, Minn. (Fig. X)

At this plant the normal monthly output is 67 general and 65 light repairs with about 600 men.

The passenger car shops lie between locomotive shops on the east and the freight repair department on the west. It consists of four main buildings, two on either side of a transfer table, with a mill building at the north end. The cabinet, pattern and upholstery shops are on the second floor of the northwest building. Truck repairs are made in the north end of the southeast building, and the sash and door work is done in the south end. Air brake work is done in the northwest building. Dynamo baggage cars are tested under steam on tracks alongside the power house. Cars are stripped, washed, repaired, painted, and trimmed all on the same track, in any of the four shops. Sand blasting is done in the open on yard tracks.

I. C. Shops at Burnside, Ill. (Fig. XI)

This plant has a normal output of 60 generals and 20 to 30 light repairs per month with 250 to 300 men.

It forms a part of a large plant where repairs are made to all classes of equipment. The Locomotive Department is on the south and the old freight car department is on the north with the main line to the east. It is a transverse layout, consisting of two main buildings, one used for painting and the other for coach repairs, with a transfer table between. The buildings are wide enough to hold two cars per track. Back of the coach repair shop is a building containing the freight car repair shop, the mill and cabinet shops. The upholstery, sash and door, plating and paint mixing work is done at the north end of paint shop. The wheel and axle shop is located at the north end of the repair shop and the first two tracks at the north end of this shop are used for truck repairs. The tin shop is located at the south end of the repair shop. Cars are washed on tracks at south end of paint shop.

Cars are stripped in the yard in good weather, or on wash tracks if not favorable. From the washing tracks the car is taken to repair shop, then back to paint shop for painting and finishing. Paint is burnt off on wash tracks. Steel cars are not sand blasted but paint is removed with a solution on the wash tracks.

N. P. Como Shops at St. Paul (Fig. XII)

In normal times the output from this shope is 40 general repairs with 350 to 400 men.

The passenger car repair plant consists of three main buildings, two of which are devoted to coach and painting and the third to miscellaneous work. A long transfer table lies between the two main buildings and serves also the miscellaneous and a small freight car shop. In the miscellaneous building are the truck shop, the wheel and machine shop, the tin shop, air brake room, and steamfitters' benches. The wood mill also occupies one section of this building. The upholstery and cabinet work occupies the second floor. The two coach shops are each divided into two sections, the north ends being used for repair work and the south ends for painting. Each track holds two coaches. The connecting structure at the south end of the transfer table is used for paint mixing.

The cars are taken to coach repair shop either via transfer table or directly from tracks, stripped and repaired. It then moves to paint shop where it is washed, painted, and trimmed. Paint is burned off in the repair shop and sand blasting is done in the open yard. The six-wheel trucks are taken to truck shops for repairs but the others are repaired on the coach repair track.

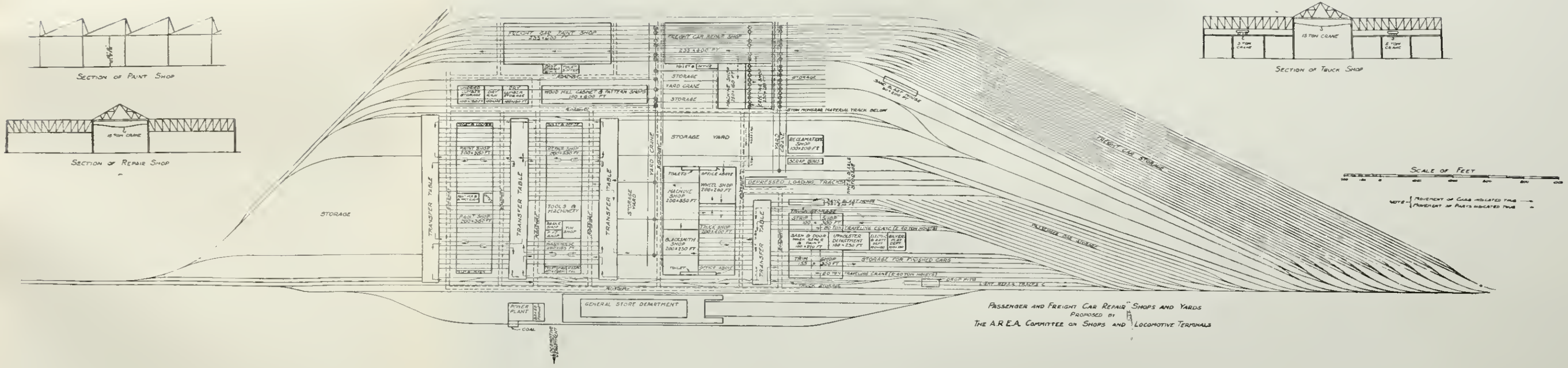
Pennsylvania Shops at Altoona, Pa. (Fig. XIII)

During normal times the output from these shops is 70 general and around 160 light repairs per month with about 1,200 men.

The passenger car department is confined between the main line on one side with the city on the other, and the freight car repair plant at the other end.

The plant consists of two passenger car erecting or repair shops with longitudinal tracks and one coach paint shop with transverse tracks served by a transfer table. The larger repair shop has six tracks holding three or four cars each. The smaller shop, with three tracks holding five cars each, has an overhead traveling crane and is used for heavy car repair work, locomotive cab work, and the building of new coach tracks.

The coach paint shop has 19 tracks holding two cars each. Two tracks are set aside for washing. The sash and door varnishing is done in one end and at the other end are constructed three ovens for baking the paint and an addition for paint mixing. The mill, the blacksmith and the machine shops are in separate buildings centrally located.



Section of Paint Shop
Section of Repair Shop
Section of Truck Shop
Scale of Feet
Storage
Transfer Table
Storage Yard
Freight Car Storage
General Store Department
Power Plant
Passenger and Freight Car Repair Shops and Yards
Proposed by
The A.R.E.A. Committee on Shops and Locomotive Terminals

Fig. I.

The tin shop is on the second floor above machine and sheet metal shops. Plumbing and upholstery work is done in a separate trimming shop where coaches are taken to be trimmed after paint work is completed.

Cars on entering shops are stripped in the yard on tracks adjacent to trim shop, taken to wash tracks in paint shop, then moved to one or the other of the repair shops, back to the paint shop and finally to the trim shop. Sand blasting is done in an isolated building back of the old roundhouse.

M. St. P. & S. S. M. Shorahan Shops at Minneapolis (Fig. XIV)

In normal times about 21 general repairs are turned out per month at these shops with around 200 men.

The passenger car shops form a part of a central plant where repairs are given to all classes of equipment. The Locomotive Department lies to the east and the freight repair tracks are on the north. The passenger car plant consists of two coach shops, one on either side of the transfer table and a wood mill, which is located to the south of them. The sash and door work is taken care of on the second floor of the west shop. The upholstery, cabinet, and brass shops are located in the second floor of the mill building. Electrical and battery work is done at the north end on the first floor of each coach shop. The machine and blacksmith shops, which lie to the east, are used jointly with the Locomotive Department. The tin shop is on the second floor of the machine shop. The wheel shop is located in a separate building, at a considerable distance off to the south of the coach shops.

Both coach shops are used for repair and paint work. Cars are taken into the shop, stripped, washed, repaired, painted, and trimmed on the same track. Trucks are repaired in the yard and the sand blasting is also done in the yard.

Union Pacific Shops at Omaha, Neb. (Fig. XV)

The monthly output in normal times for this plant averages 28 general and five to ten light repairs with about 175 men employed exclusively on passenger car work.

These shops form a part of a large central plant where repairs are given to all classes of equipment. The car shops consist of two main buildings separated and served by one transfer table. With the exception of the wood mill and paint supply house, all departments in connection with passenger car work are under the roofs of these two shop buildings. The building on the south side of the transfer table is used for the paint shop. At the east end of this building is the truck and wheel shop and at the west end is the sash and door department. The coach repair shop joins on to the steel freight car repair shop and lies on the north side of the transfer table. Miscellaneous departments such as the upholstery, cabinet, plating, etc., are located at the west end of the coach repair shop.

The cars on entering the shops are taken to a permanent hoist, which is located outside at the west end of the repair shop. Here the bodies are removed from the trucks and placed on dollies. Car body is stripped at this point, after which it is taken into either the repair or paint shop where it is washed, repaired, painted, and trimmed on the same track. After the car body is finished, it is brought out to the permanent hoist and the trucks applied.

Wabash Shops at Decatur, Ill. (Fig. XVI)

In normal times the output of this plant is 13 general and 40 light repairs per month.

There is only one coach shop. It is flanked on the south by the storehouse and on the north by a miscellaneous building. The Car Department lies to the east of the Locomotive Department and the two are entirely separate. The freight car department lies to the south of the coach shop between it and the main line tracks. The coach shop has four longitudinal tracks holding five to six cars each. In the miscellaneous building are the cabinet, pattern, sash and door, upholstery, tinshop, and plating departments. The blacksmith and machine shops occupy a building lying to the south of the storehouse and coach shop with the wood mill to the west.

The cars are taken into the coach shop where they are stripped, washed, repaired, and trimmed on the same track. The trucks are repaired on the same track with the car. Sandblasting of the steel cars is done in the open yard.

Pullman Company Shops at Pullman, Ill. (Fig. XVII)

There are five separate shops in which cars are repaired, built and painted. These shops have 85 tracks holding two cars each and 15 tracks holding one car each, making a total capacity of 185 cars. Main shop buildings are so arranged that they are served by transfer tables on one or both sides, and all buildings have transverse tracks. With the exception of two large coach shops, all of the main buildings are grouped together at the southeast corner of the plant. The plant, of course, is used for both the manufacturing of new cars and the repair of existing equipment, and has been extended from time to time to keep apace with the growth of the Pullman Company.

Cars coming into the plant for repairs are stripped in the yard, opposite the upholstering shop. Trucks are removed from the cars in several places in the yard and also in the shop. The cars are then taken to the repair shop where the necessary repairs are given and are then removed to paint shop for finishing and trimming. The cars under construction progress through from shop to shop, starting in with the underframe work in the steel shop and ending in the paint shop where they are finished and painted.

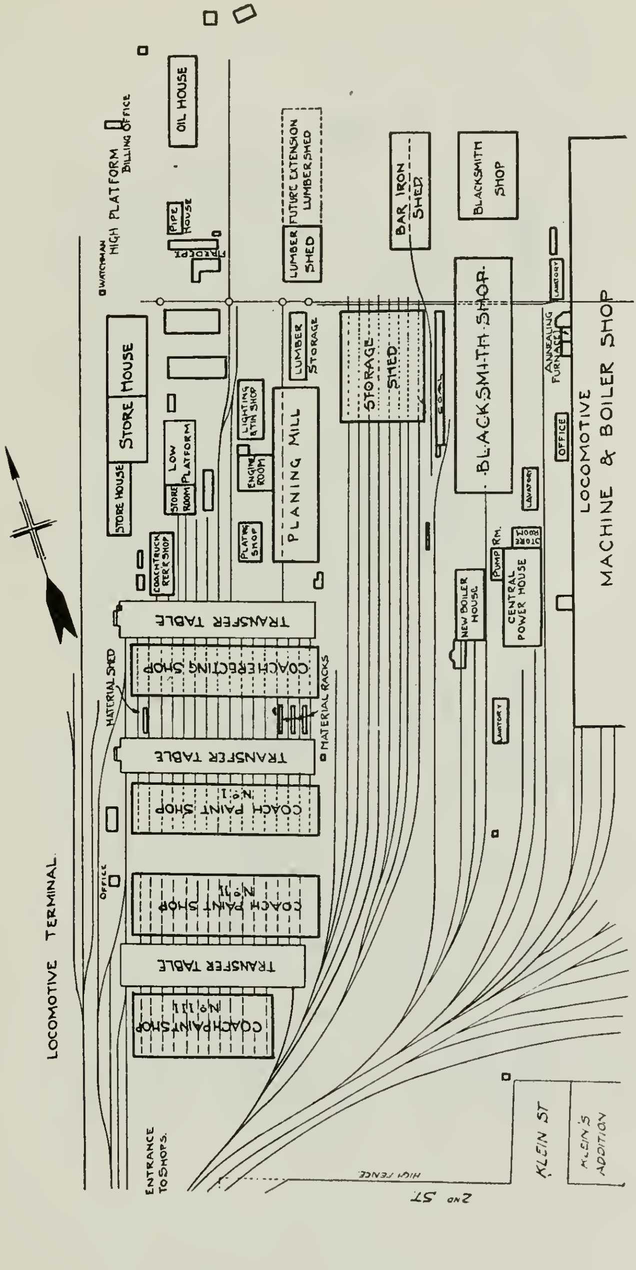


Fig. 11—A. T. & S. F. Shops at Topeka, Kansas

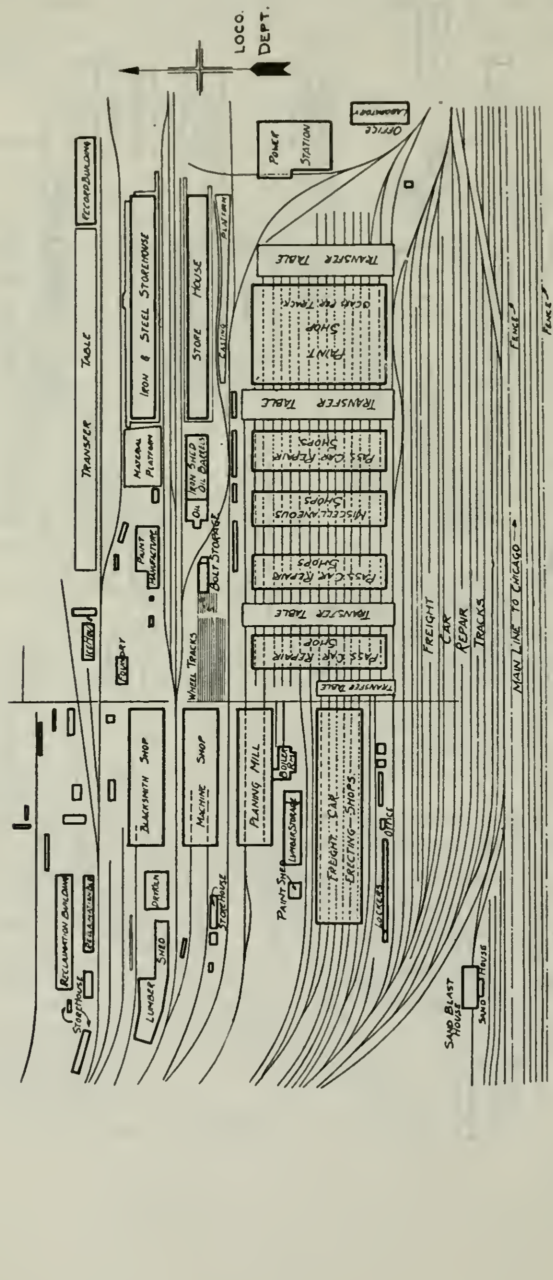


Fig. III—C. & N. W. Shops at Chicago

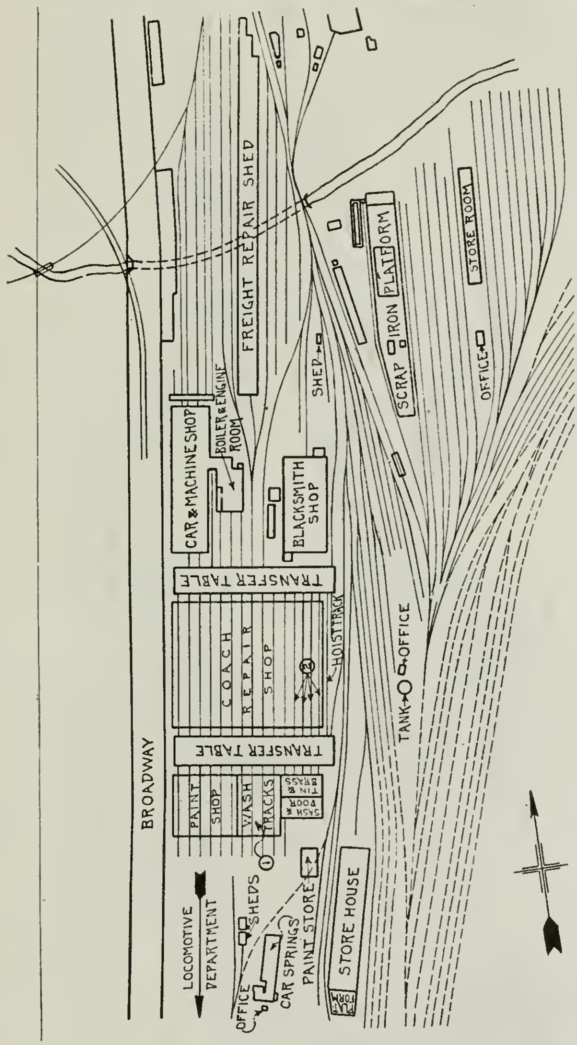


Fig. IV
Aurora Shops
C. B. & Q. R.R.
General Plan

① Sash varnish room & upholstery shop on 2nd floor
② Four tracks used for truck repairs

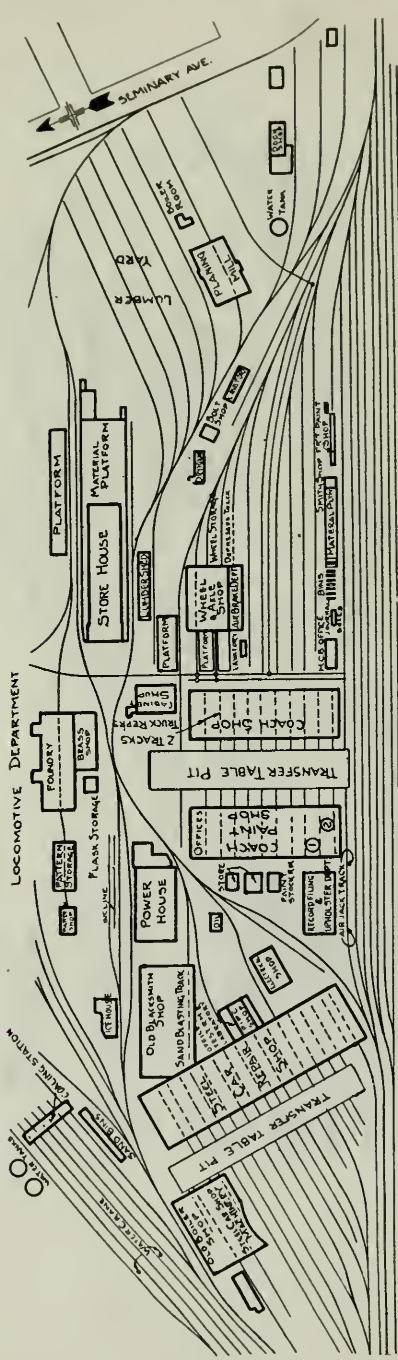


FIG V
BLOOMINGTON, ILL.
CHICAGO & ALTON R.R.
GENERAL CAR PLAN

① SASH WASH ROOM ON 1ST FLOOR
② VARNISH ROOM ON 2ND FLOOR

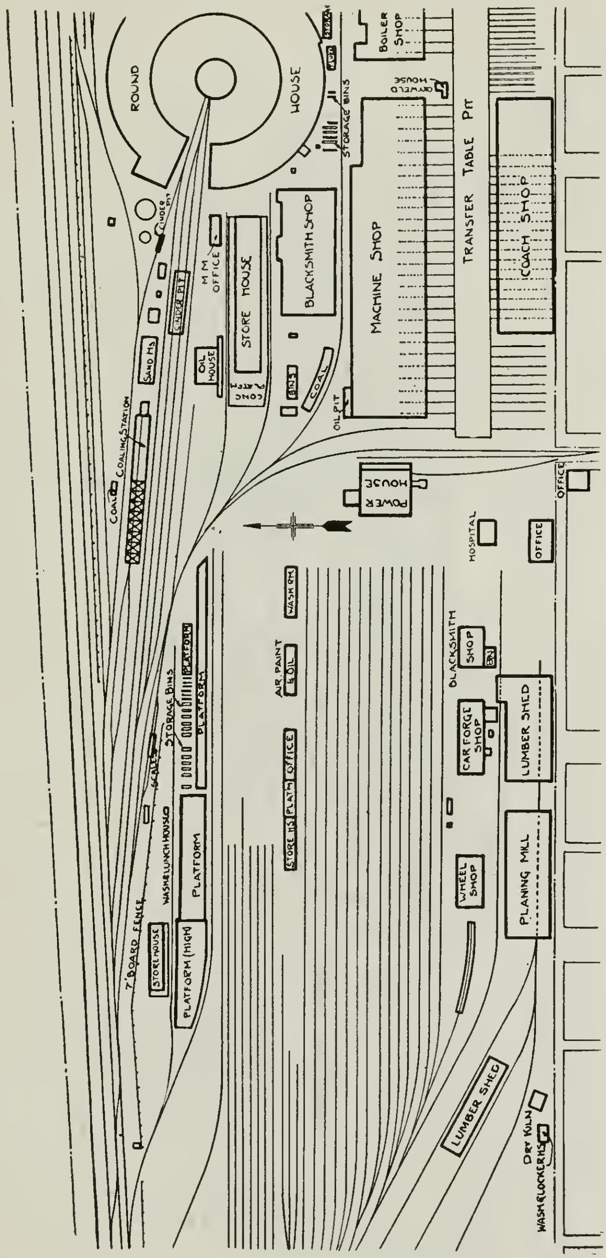


Fig. VI—C. & E. I. Shops at Danville, Ill.

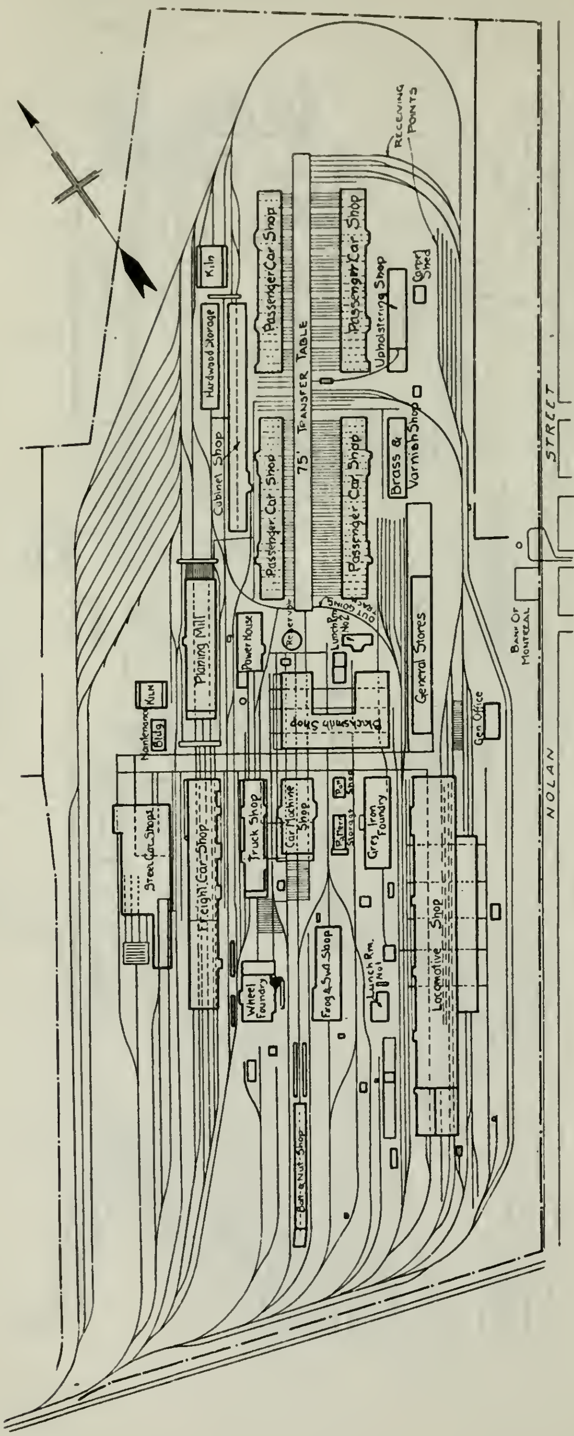


FIG. VII—C. P. R. ANGUS SHOPS AT MONTREAL

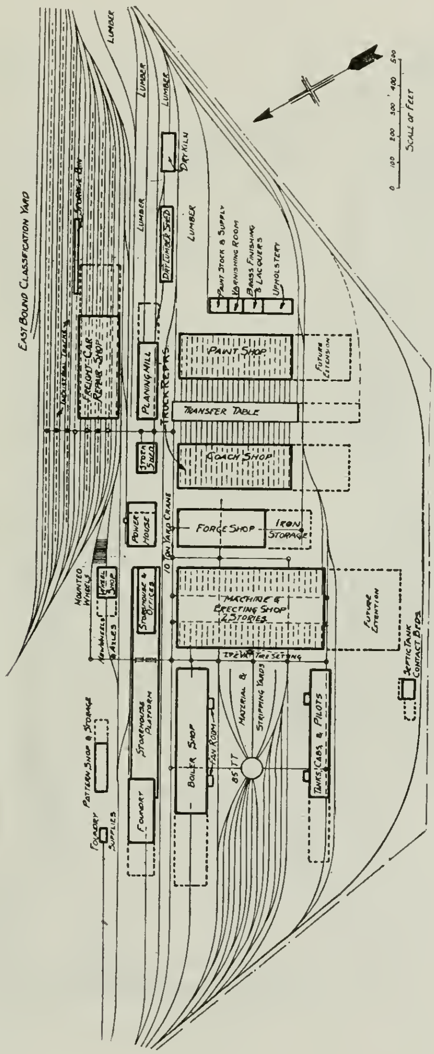


Fig. VIII—C. C. C. & St. L. Shops at Beech Grove, Ind.

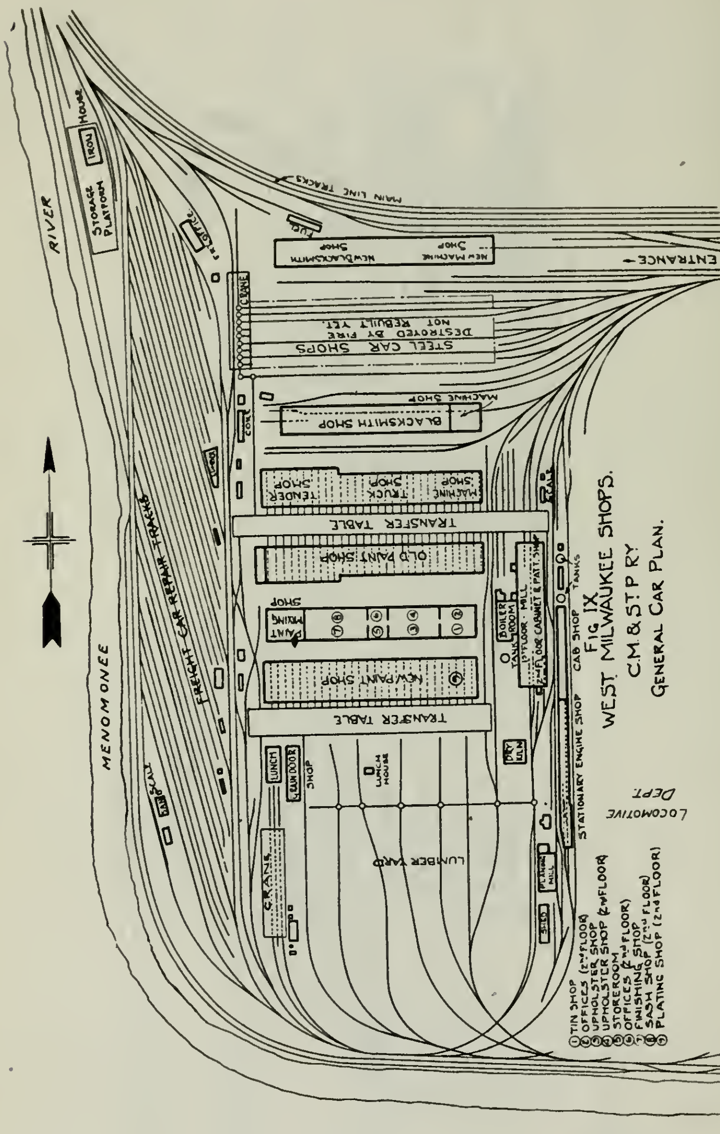


FIG. IX
WEST MILWAUKEE SHOPS.
C.M.&ST.P. RY
GENERAL CAR PLAN.

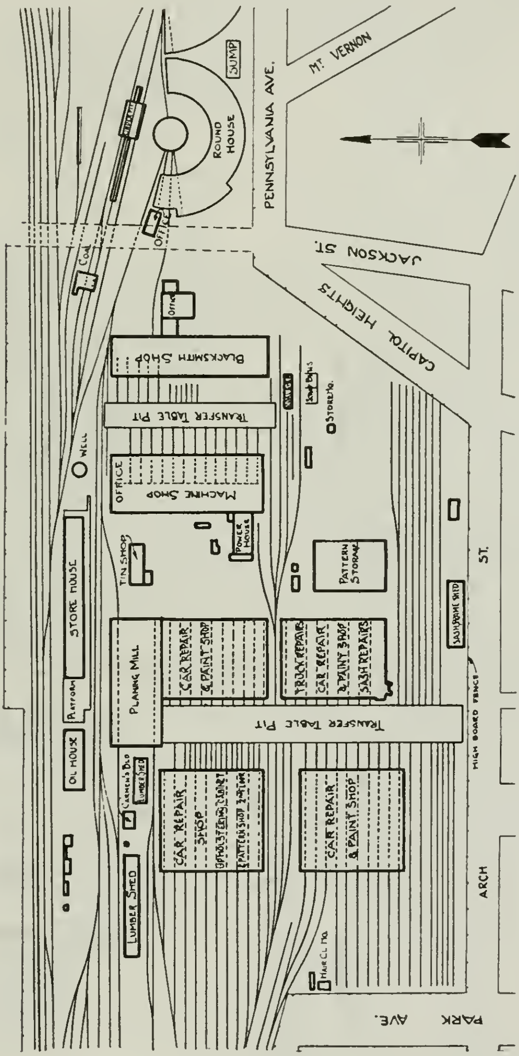


Fig. X—G. N. Jackson Street Shops at St. Paul, Minn.

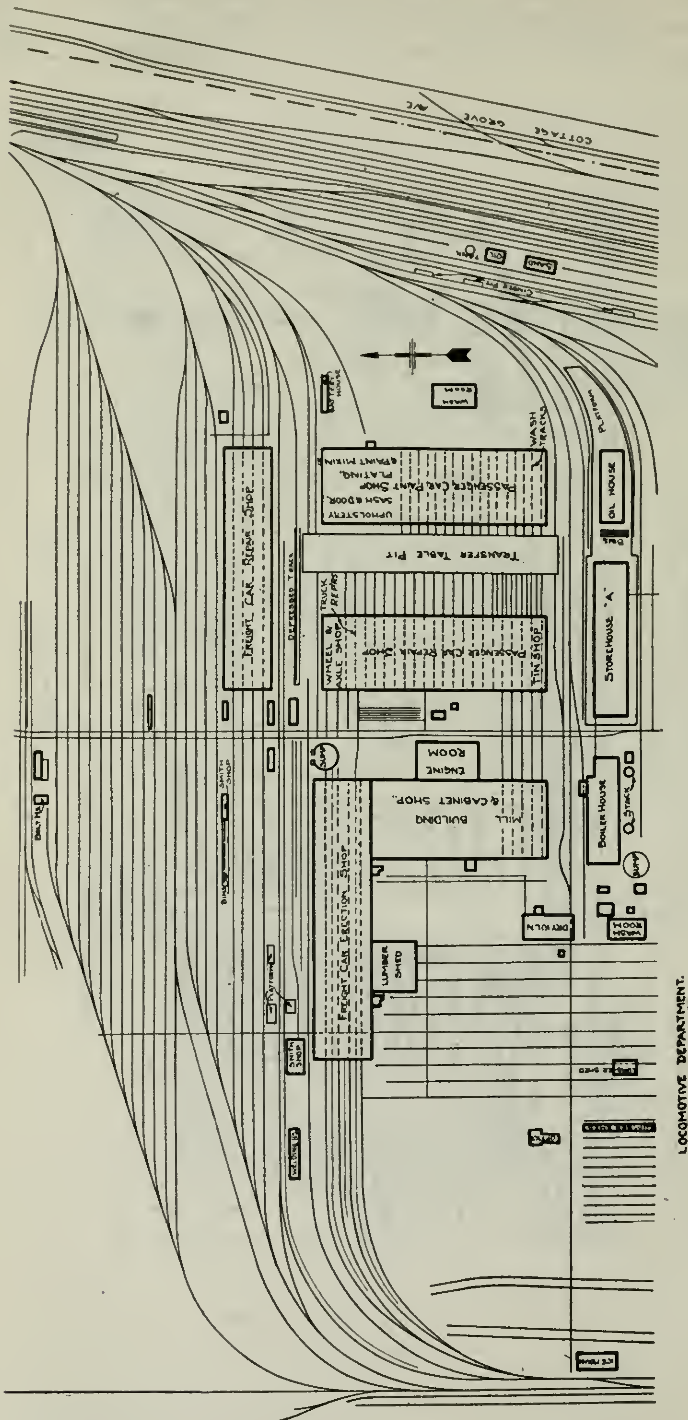


Fig. XI—I. C. Shops at Burnside, Ill.

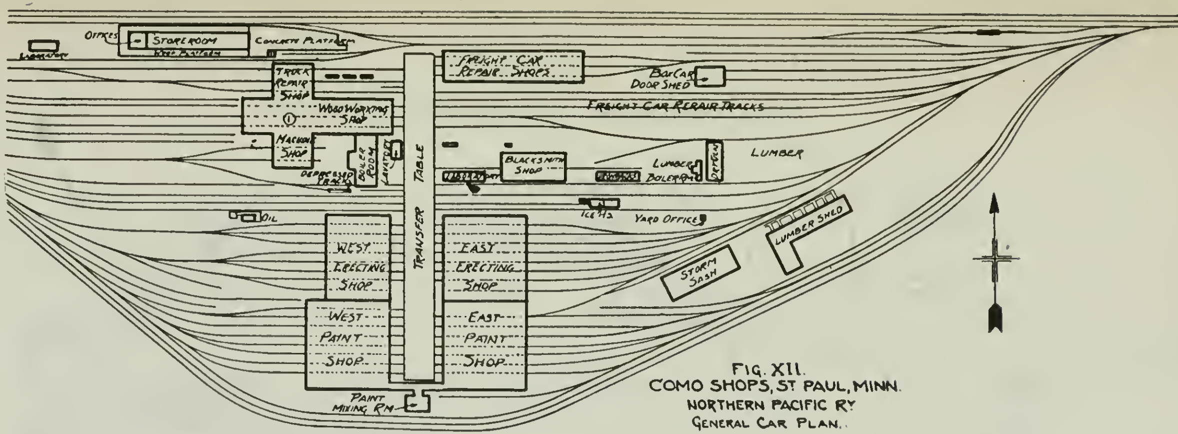


FIG. XII.
COMO SHOPS, ST PAUL, MINN.
NORTHERN PACIFIC RY
GENERAL CAR PLAN.

① UPHOLSTERY AND CABINET WORK ON 2ND FLOOR

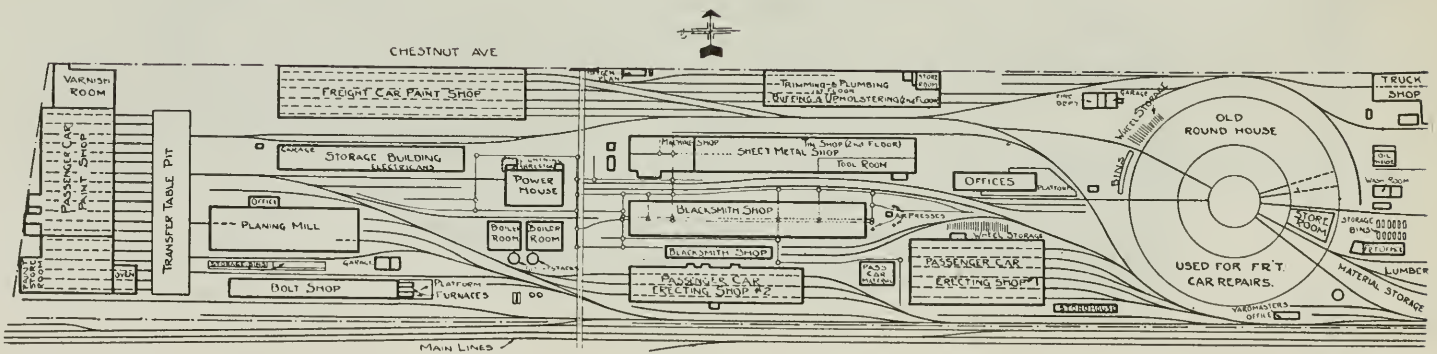


FIG. XIII—PENNSYLVANIA SHOPS AT ALTOONA, PA.

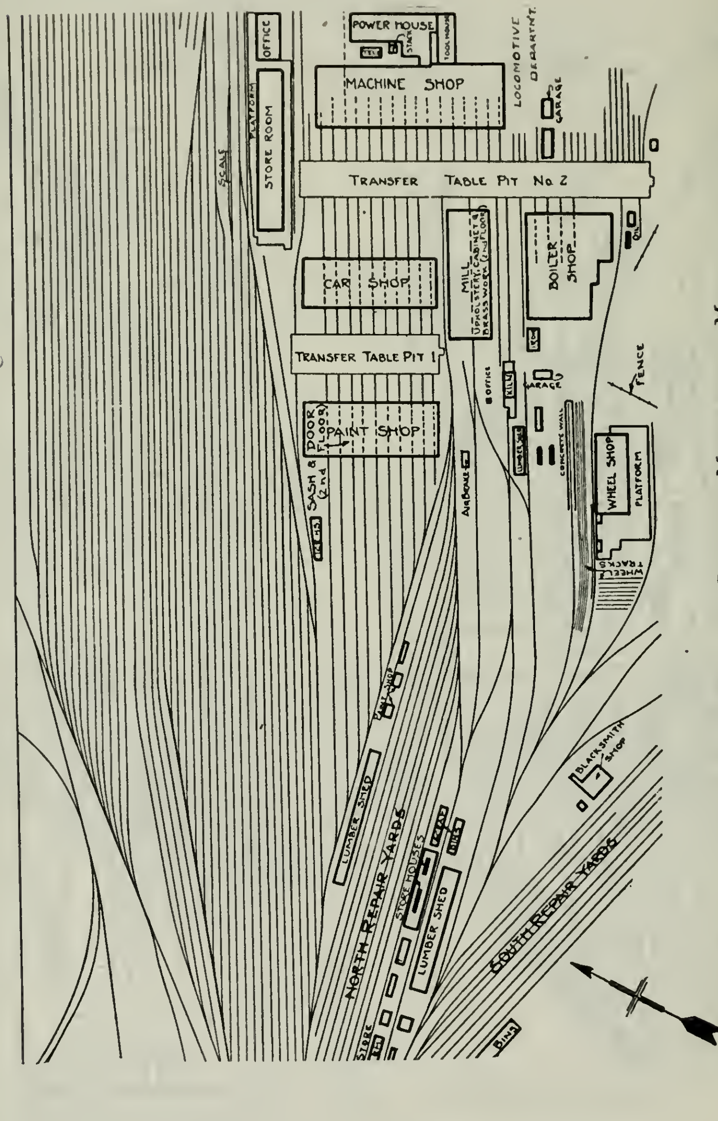


Fig. XIV—Soo Line Shops at Minneapolis, Minn.

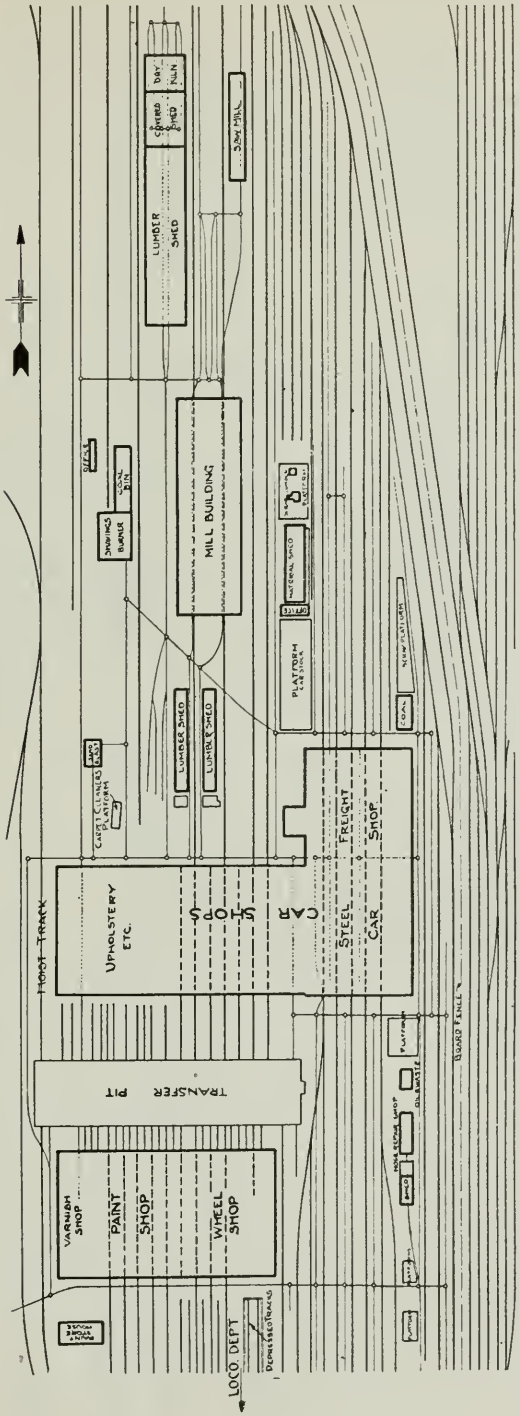


FIG. XV—UNION PACIFIC SHOPS AT OMAHA, NEB.

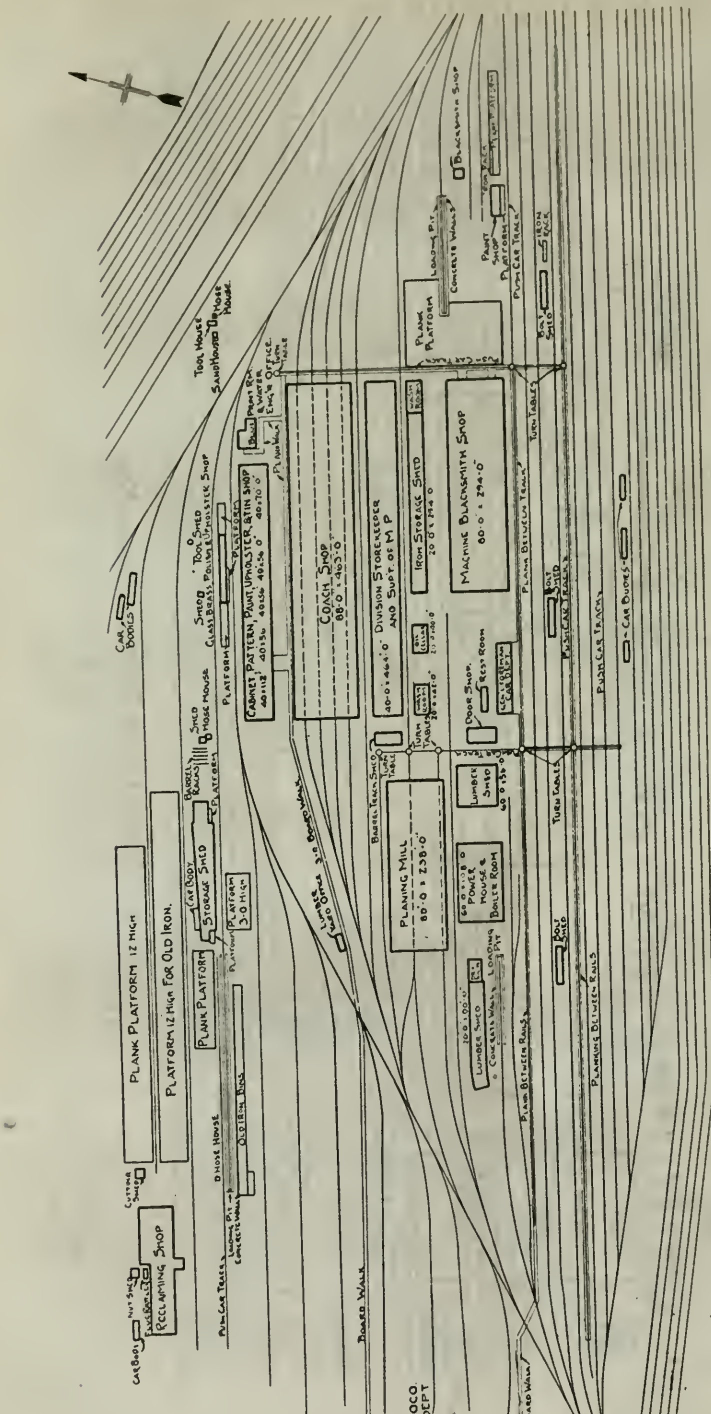


Fig. XVI—Wabash Shops at Decatur, Ill.

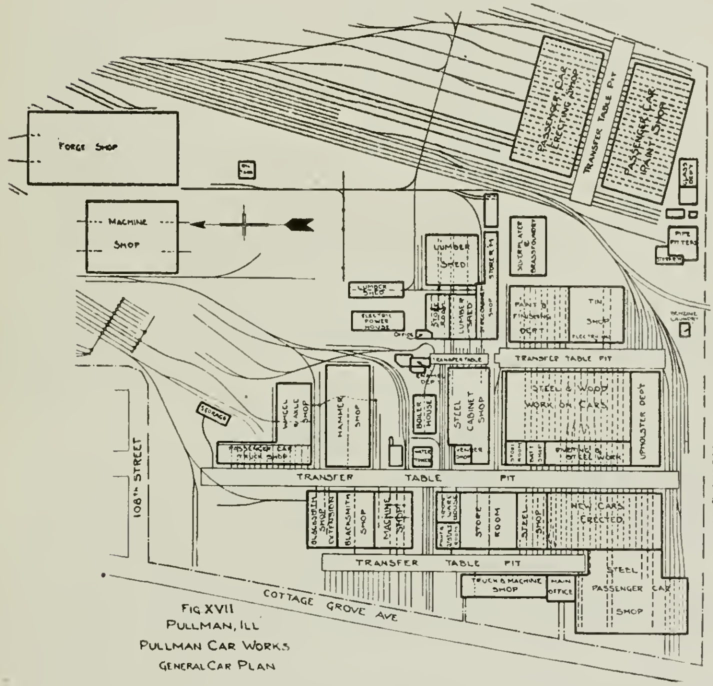


FIG XVII
PULLMAN, ILL
PULLMAN CAR WORKS
GENERAL CAR PLAN

REPORT OF COMMITTEE I—ON ROADWAY

J. R. W. AMBROSE, *Chairman;*
H. G. AYLESWORTH,
E. W. BAYER,
C. W. BROWN,
H. W. BROWN,
R. K. BROWN,
A. S. BUTTERWORTH,
C. C. CUNNINGHAM,
W. C. CURD,
C. A. DALEY,
S. B. FISHER,
R. D. GARNER,
R. C. GOWDY,
F. M. GRAHAM,
H. HAWGOOD,
E. G. HEWSON.

C. M. MCVAY, *Vice-Chairman;*
W. H. JAEKLE,
A. A. MATTHEWS,
W. H. PENFIELD,
P. PETRI,
FRANK RINGER,
H. A. ROBERTS,
R. B. ROBINSON,
R. A. RUTLEDGE,
G. L. SITTON,
E. G. TABER,
H. E. TYRRELL,
C. E. WEAVER,
W. H. WOODBURY,
J. C. WRENSHALL,

Committee.

To the American Railway Engineering Association:

As instructed by the Board of Direction, your Committee has condensed its report as much as possible. Sub-Committees were named to report on the various subjects assigned and their reports will follow; information relating to the activities of the Committee during the past year has been given in the various Bulletins.

ACTION RECOMMENDED

1. That the definitions of terms under Revision of Manual (Appendix A) be approved for insertion in the Manual.

2. That report on shrinkage and swell of grading material (Appendix B) be received as information.

3. That the conclusions in reference to methods employed and results secured in the treatment of sliding cuts and fills and soft spots in excavation and embankments (Appendix D) be approved and inserted in the Manual.

4. That report on effect of heavier power and increased tonnage upon roadbed previously considered stabilized (Appendix D) be received as information.

5. That report on filling of bridge openings (Appendix E) be received as information.

6. That the conclusions in report on "Ditching" (Appendix F) be approved and inserted in the Manual.

7. That report on chemical killing of weeds (Appendix G) be received as information.

8. That report on design and use of reinforced concrete culvert pipe (Appendix H) be received as information.

9. That report on excessive cost of maintenance during the early period of operation (Appendix I) be received as information.

10. That the suggested outline of work (Appendix J) be referred to the Board Committee on Outline of Work.

Recommended Outline of Work for the Ensuing Year

Your Committee recommends the following subjects for the coming year's work:

1. Study the Manual and submit revisions thereof, particularly the grading specifications.
2. Study and report on the economics of bridge filling.
3. Study and report on the effect of heavier power and increased tonnage upon roadbed previously considered stabilized.
4. Study and report on chemical killing of weeds.
5. Study and report on excess costs of maintenance during the early period of operation.
6. Report on the use of corrugated metal culverts in railway work and prepare specifications for material and workmanship.

Respectfully submitted,

The Committee on Roadway,

J. R. W. Ambrose, *Chairman.*

Appendix A

(1) Revision of Manual

Your Committee recommends the following definitions for the Manual:

Casting (verb).—Disposing of excavated material by a single operation either by hand or machinery.

Station Men (noun).—Men engaged in station work.

Station Work (noun).—A small piece of grading work extending over one or more stations.

Appendix B

(2) SHRINKAGE AND SWELL OF GRADING MATERIAL

C. M. McVay, *Chairman;*
E. J. Bayer,
H. W. Brown,
W. H. Woodbury,
F. M. Graham,
P. Petri,

Sub-Committee.

Considerable correspondence has been carried on by the Sub-Committee and additional information requested from various sources, but very little has been received that would add to what has already been reported.

On account of the varying formations throughout the country and the different methods of handling them in doing work, the results are difficult of comparison.

Taking the eastern portion of the country for example, we have successively starting on the north, the granite formation, then the so-called gravel formation, part of which would be classed by some engineers as loose rock, then through the limestone areas and following this the sandstone and clay and then the loam and sand. All of these formations have many varieties and ramifications and each give different results when used as grading material.

All embankments on our railroads today are made from material from three sources, namely the cuts or excavations necessary on the line, borrow pits adjacent to or near the line, and industrial waste given to the railways for disposal. Many embankments are a combination of material from all three sources, and while it is difficult to get definite information on the relative yardage in cut and fill for material from the first two sources, it is impossible to get anything on the third.

The Committee believes it is possible to obtain the necessary data to make a comprehensive study of this subject if the members will cooperate with them, and with this end in view we submit herewith a form with the request that members in doing new work, have the information collected as outlined, particular attention being given to question No. 6, for this point has been the Committee's greatest difficulty.

Form for Reporting Grading Work

1. Location of work.
2. Material in excavation.
    (a) Yardage.
    (b) Classification.
    (c) Depth of cut below surface.
3. Material in embankment.
    (a) Yardage.
        1 year later.
        3 years later.
        6 years later.
    (b) Material on base of embankment.

4. Method of excavating.
   (a) Capacity of steam shovel dipper.
   (b) Capacity of dump cars.
   (c) Length of haul to embankment.
   If by teams or grading machines.
   (d) Type and capacity of scrapers or wagons.
   (e) Average length of haul.

5. Building embankment, if by trestle state:
   (a) Height of trestle.
   (b) Size of stringers and when pulled.
   (c) Were slopes pulled out and how.
   If by teams.
   (d) Thickness of layers.

6. If any additional filling material was put on the embankment during settling period, so state, showing material and yardage.

7. Weather during work.

8. General information.

Some interesting information has been received from the Southern Pacific on the subject of shrink and swell. This Company made an investigation of eight railway embankments on a line, the building of which was discontinued in 1912 and work has not been resumed. Track was not laid on these embankments, therefore the shrinkage of the material was entirely natural and not augmented by trains passing over them.

The results obtained would probably be different had the fills been subjected to the compressing action of trains. An analysis of the results of the investigation shows that in every case other material than common earth was encountered in the excavation and placed in the fills. Each embankment had rock in some form.

The fill containing the greatest percentage of earth shows the greatest shrinkage and those with the greatest percentage of rock show the greatest swell. In the eight cases about 15 per cent. of the material was common earth, 65 per cent. was cemented material, 14 per cent. trap rock and the balance more or less of a solid formation.

Cross-sections were available for this work as of 1912 both as to material removed from excavation and material placed in embankment, and it was found that in six of the eight embankments the calculations showed an increase of some 6.61 per cent. to 21.34 per cent; the two remaining examples show a decrease or shrinkage of 5.67 per cent. and 9.83 per cent. The eight fills taken together show a swell of 7.768 per cent. above that measured in excavation.

In 1920 the fills were again carefully cross-sectioned and the results show that in four of the eight cases there was a swell ranging from 0.997 per cent. to 17.24 per cent., and the four remaining cases a shrink of from 1.27 per cent. to 17.34 per cent. Taking an average of the eight fills a shrinkage of 0.362 per cent. is shown.

Information has not been secured as to the method of filling used in making the fills. As mentioned in previous reports of this Committee, fills made with teams and scrapers are generally compacted much more than fills made by dumping from trestle, and when the fill is complete, it generally stands in good shape with a less amount of settlement. Fills made by dumping from trestle will be settling for a considerable period and should be enlarged as per previous reports of this Committee now in the new Manual.

Members who have abandoned embankments on their line for which the original notes are available are requested to resection them and submit the information to the Association.

The Committee has found nothing that would lead them to change any conclusions previously made as to this subject. No further density tests have been reported and there is nothing to add to the report of a year ago in this regard. It is hoped that some of the railroads will do more with this matter in the ensuing year.

It seems to be impossible to find any rule for the swell of grading material, but it seems that the method of handling has considerable to do with the result secured. This is especially true with solid rock in any of its formations, granite, limestone, sandstone, etc.

The Committee can see no reason to change any of its previous conclusions in its reports on shrinkage and swell. No data has been brought to light which would in any way change the general aspects of the subject.

The Committee again recommends that the subject be closed until additional investigation and experiments are available on this subject.

Appendix C

(3) METHODS EMPLOYED AND RESULTS SECURED IN THE TREATMENT OF SLIDING CUTS AND FILLS AND SOFT SPOTS IN EXCAVATIONS AND EMBANKMENTS

C. A. DALEY, *Chairman;* R. D. GARNER,
C. W. BROWN, E. G. HEWSON,
R. A. RUTLEDGE, *Sub-Committee.*

Your Committee wishes to draw the attention of the members to the report of the Roadway Committee under the Chairmanship of Mr. George H. Bremner, contained in Volume 10, Part 2, 1909, where a large amount of very valuable information on this subject was submitted and from which the conclusions now in the Manual were deduced.

The treatment of slides and soft spots which are the result of water pockets formed in the track has not been considered in this report, as this subject has already been well covered in recent investigations and reports by the Roadway Committee. This report covers slides and soft spots, the causes of which are of different origin and are more deeply seated.

In order to obtain information as to the different methods employed and the results obtained under different geological and climatic conditions, a questionnaire was sent out to fifteen of the larger railroads in different parts of the United States and Canada, the replies received being embodied in the following report:

Slides

Slides will be treated in two classes, namely:

Class "A"—Surface slides of small volume.

Class "B"—Slides or slips of great volume which do not as a rule come as an avalanche but are of slow movement.

("A") Class "A"—Surface slides occur in nearly every class of material and combination or mixture of materials, except rock, in both excavations and embankments and are caused largely by the ground becoming saturated. The extra weight of the water in the ground upsets the equilibrium and reduces the cohesion and a slide is the result. In North climates the action of frost greatly facilitates the action of the water by opening up crevices and making the ground porous.

TREATMENT IN EXCAVATIONS.—Surface water should be kept from the face of cuts as much as possible by the use of intercepting ditches constructed well back from the top of cut. These ditches should be constructed with care and should be well maintained so as not to let pockets form to hold water that will eventually soak into the ground and may be the cause of a slide.

Good results have been obtained in deep cuts where excavations have been taken out in such manner as to permit it by the construction of ditches on a table or shelf part way up the slope and the water carried off.

Where cuts have a large number of springs on their surface, small concealed tile drains have been laid down the slopes to the ditches in order to keep the water from the numerous springs and saturating the soil.

In many cases excellent results have been obtained by facing cuts with layer of engine cinders or fine slag about six inches deep. This tends to distribute any water reaching the face of the cut and prevents cutting, and also lessens the action of the frost. Where this method is used the cut should be faced to a reasonably true plane before the application of the coating.

In cities and towns sodding of slopes has been carried out with good success, but on account of the cost, this method of treatment has been confined mostly to densely inhabited districts where the esthetic value of this method is given consideration.

The planting of vegetation (not trees) on the slopes of cuts has proven very successful in the cure of slides. A mixture of seed that has been found very desirable for this purpose, in climates where it will grow, is two parts by weight of alsyke, two parts alfalfa and one part blue grass seed. Where the soil is poor it is desirable to enrich it with street sweepings or manure. Small wooden stakes should be driven into the ground at about twelve inch centers to hold the dirt and vegetation until the roots are long enough to get a good hold in the original soil. It is also well to sow oats or rye with the seed as this shades and protects the smaller grass. The real success, however, in obtaining growth of vegetation on cuts to assist in preventing slides is to properly care for the young grass for the first couple of years. Mowing should be done frequently and the grass should not be allowed to go to seed Japanese honeysuckle and Bermuda grass have also been planted on cuts with good results.

Embankments.—Small slides of embankments are treated in practically the same manner as above mentioned in cuts except for the drainage. The slopes have been sodded and faced with cinders in a manner similar to the treatment of cuts and with equal success. The flattening of the slope and the weighting of the toe of the slope with derrick rip rap where it is practical to do so, and where the toe of the slope is subject to the action of running or standing water, has proven successful. Embankments that have given trouble for a long time when treated in this manner have become stable. In one case it was necessary to place rip rap well out in the bed of the stream to accomplish the desired result. Where the embankment is not subject to the action of water, the use of either two or three man rip rap will answer the purpose equally well. The same result has been accomplished by the construction of a false berm approximately one-third the height of the embankment.

In low-lying country where there is a large amount of surface and ground water, considerable trouble has been experienced in holding fills. To overcome this ditches have been dug near the right-of-way line some distance from the toe of the slope and the ground water level lowered with exceedingly good results. The depth of the ditches to be dug depends on the fall that can be obtained.

In some cases where the slides are of a minor nature a timber crib or loose stone retaining wall built in the toe of the slope on an angle approximately equal to the angle of slope has proven effective.

("B") Class "B"—Slides or slips of great volume are hard to remedy. Each case must be studied and the cause determined, if possible, and this cause then removed. In nearly every case it is underground water or seepage that causes the trouble.

When a study has been made of the movement and its cause determined it is generally found that the slipping occurs on a strata of inclined rock or clay. Sometimes the strata of clay is only an inch or so thick. Water reaching the strata of rock or clay is retained and forms a lubricant which upsets the equilibrium of the mass and the slide starts. The remedy is, of course, to intercept the water and to prevent it following the strata.

The following are some interesting experiments which have recently been carried out:

1. In which the water was intercepted on a strata of clay about a hundred feet below the surface of the ground and which has proven successful in curing serious slide is reported by the Kanawha and West Virginia Railway:

"Holes were drilled about 75 ft. back of the top of slope of the cut and 75 ft. apart. A total of 11 holes were drilled ranging from 95 ft. to about 130 ft. deep. These holes were from 110 to 190 ft. from the center line of the main track. They were drilled from 8 to 10 ft. into a soapstone formation on top of solid rock 20 to 25 ft. below grade. It was necessary to case the top part of the hole in the sand clay and boulders, the balance of the hole standing in good shape without casing. As soon as the hole was drilled it was sprung and immediately loaded and shot. About 100 lb. of dynamite was placed in the bottom of rock shot and about 75 lb. in the upper or blue clay shot which was placed about at the grade of the track or a little below. The holes were filled between the lower and upper shots with sand. The holes had to be loaded and shot quickly after cleaning them, as the water ran in very rapidly. The casing was pulled after the hole was loaded and ready to shoot.

When the holes were shot there was no distortion of the face of the cut or the ground around the hole. The face of the cut was immediately dried up with the exception of a small amount of water that came over from the top in the time of heavy rain. The test is now over two years old and has so far been very satisfactory, and as the slope is now getting well covered with vegetation, no further trouble is anticipated.

The total length of holes drilled was about 1,232 lin. ft. The cost of drilling and shooting was $1,816.92, which represents a cost of approximately $1.47 per lin. ft. of hole. The work was started in May, 1919, and completed in July, 1919."

Another case of intercepting the ground water and thus curing a bad slide of an embankment built on a hillside is reported by the Southern Pacific Company as follows:

"The fill in question was on a side hill in the Santa Lucia Mountain District. It had always given trouble, but during the winter of 1909-10 it became very serious, due to the heavy rains of that winter. The settlement was so great that a very large force of men was constantly engaged, day and night, in picking up the track after the passing of each train, a steam shovel being required to furnish the material. It is estimated that the fill settled during the few months considerably over 100 ft. The sliding material was a quarter of a mile long, the original culvert broken up and carried along with the sliding material, the ground moving along in big folds and waves.

In attempting to find a solution for the trouble, we noted the absolute absence of water above the tracks, except in rainy weather, and then only in small quantities. The upper portion of the sliding fill for about 100 ft. in depth was absolutely dry, but below this 100 ft. water was traced coming out of the rim of the slide; that is, where the sliding material joined the solid hillside; below this point the hill was saturated with water. We reasoned that somewhere about 100 ft. below the track there must be a live spring of water, coming out of the hillside, possibly on the contact between two strata formations. A shaft was sunk above the track and a well defined contact was discovered. The next thing to do was to go down on the rim in the solid material, a short distance below where the water came out, and start tunnels on such a grade as to connect with the shaft above. This was done and a large amount of water picked up, one spring cut into flowing at the rate of 900 gal. per minute, and during ordinary summer conditions the water, measured at the portal of the main drain tunnel, amounted to over 1,200 gal. per minute.

Shortly after the completion of these drain tunnels the track stopped settling, and only ordinary maintenance has been required since then. Several other slides in the immediate vicinity were corrected in a similar manner."

A report from the North Pacific Coast is as follows:

"Throughout the North Pacific Coast territory slides of large volume are of frequent occurrence. The attention of the Committee is called to an article which will appear in a future number of the proceedings of the American Society of Civil Engineers by Mr. S. Murray, Assistant Chief Engineer, O.-W. R. R. & N. Company, concerning a slip of large volume which has been under treatment for a good many years. This slip is in the gorge of the Columbia River, about forty-five miles East of Portland. At this point the river cuts through the Cascade Range. On the north side of the river the present slip extends back three or four miles from the edge of the river, but the ground along the river bank has become practically stable so that no difficulty is encountered by the railroad line on that side of the river.

On the south side of the Columbia River the break from the top of the range is only a few thousand feet from the river bank. Great portions of the ground in this vicinity for a stretch of three miles along the river bank are slowly slipping toward the river, carrying with it the railroad which lies close to the river's edge.

Measurements made of this slip during the past fifteen years show a movement of 10 or 15 ft., up to 30 or 40 ft., and at some points the original stakes to mark the ground have gone beyond this point into the river and are, of course, obliterated.

This slip has caused considerable difficulty in maintaining the track. The method of treatment as outlined in the paper mentioned in the foregoing has been to run tunnels back into the slipping ground above the track to tap the veins of water and drain the small ponds and reservoirs lying in depressions on the surface. The details of construction and the results obtained are thoroughly covered by Mr. Murray in his paper and the Committee will no doubt find interesting material for study in it.

A slip of a different character has occurred in Eastern Oregon on a spur of the Blue Mountains. At this point an area of some three or four hundred acres lying along the track for a distance of about a mile has been gradually slipping down the side of the mountain, carrying the track with it. The movement has been very slow ordinarily, although at times it has been of sufficient amount to endanger the track. A study of the character of the ground at this point shows a surface strata of rock and clay to a depth of 2 or 3 ft. Beneath this strata is another of yellow clay ½ to 2 in. in thickness; below the yellow clay, coarse boulders and blue clay.

The yellow clay has acted as a lubricant on the surface strata, permitting it when wet to move bodily. The treatment in this case has been to run a trench through the natural drainage channels up the side of the mountain, shore it with heavy timbers and extend branches at frequent intervals from it over the slipping area. By this means it is hoped to keep the strata of yellow clay sufficiently free from water to prevent saturation and thus stop the slipping."

In a good many cases where the volume of the slip amounts to several thousand yards, the movement has been stopped by the use of concrete retaining walls, or pile bulkheads. A concrete retaining wall can be used only where a good foundation is procurable and its use is, therefore, considerably limited. In many cases, pile bulkheads have been the correct solution.

In the case of such slips the movement usually occurs only during the rainy season and, of course, the saturation of the ground decreases the angle of repose. Ordinarily the material is very nearly stabilized and only a small force is required to counteract any tendency to slip. For this reason pile bulkheads effectively offer the necessary resistance to hold a seemingly large mass in equilibrium.

Concrete retaining walls and piles have been used in an effort to cure slides of this class but in most cases the best that can be said for this method of treatment is that it affords only temporary relief, for the retaining wall will eventually slide at the base or tip over and the piles crowd out.

Soft Spots.—Soft spots in excavations and embankments, the origin of which is the result of geological formation, are hard to contend with and no uniform treatment can be applied to all cases.

A method that has been successfully used in both excavations and embankments is the use of long ties.

One of the railroads in the Northwest reports an effective method of treatment by the construction of a reinforced concrete slab 12 in. thick, on which the track is carried. The foundation for the concrete slab is prepared by leveling off the sub-grade and applying a 12-in. layer of good engine cinders. The cinders furnish good drainage and the concrete slab uniformly distributes the load.

In some cases soft spots in cuts have been treated by driving piles along the ballast line with the idea of confining the material, and by driving pile butts from 6 to 12 ft. in length spaced from 3 to 4 ft. directly under each rail and sinking them 2 or 3 ft. below sub-grade. The latter method is reported as being more satisfactory.

Piles have been driven in embankments both along the ballast line and under the rail in a manner similar to the method reported above but the results do not appear to be as satisfactory.

An effective method reported in the treatment of soft spots under embankments is the widening of the embankment until a point is reached where the pressure, due to the load, is distributed over a very large area.

CONCLUSIONS

Slides.—Your Committee recommends the substitution of the following conclusions for those published in the new Manual, as follows:

(1) The primary cause of slides is the lack of proper drainage.

(2) In the construction of a new line when conditions indicative of future trouble with soft spots or slides are encountered, special attention to the diversion of the springs or streams which are likely to cause the trouble should be given.

(3) Conclusion 1 in Manual becomes Conclusion 3.
Conclusion 2 in Manual becomes Conclusion 4.
Conclusion 3 in Manual becomes Conclusion 5.
Conclusion 4 in Manual becomes Conclusion 6.
Conclusion 5 in Manual becomes Conclusion 7.
Conclusion 6 in Manual becomes Conclusion 8.
Conclusion 7 in Manual becomes Conclusion 9.
Conclusion 10. Facing the slopes with a coating of engine cinders or fine slag will prevent small slides.
Conclusion 8 in Manual becomes Conclusion 11.
Conclusion 9 in Manual becomes Conclusion 12.

Soft Spots.—Where soft spots cannot be effectively drained the bearing area of the track structure must be increased.

Definition of Soft Spot.—Soft spots are small areas in excavation or embankment, or the sub-soil under an embankment, saturated with water and having a relatively small supporting power.

Appendix D

(4) EFFECT OF HEAVIER POWER AND INCREASED TONNAGE UPON ROADBED PREVIOUSLY CONSIDERED STABILIZED

R. C. Gowdy, *Chairman;*
R. K. Brown,
H. Hawgood,
H. A. Roberts,
E. G. Taber,
Sub-Committee.

Your Committee has had considerable discussion with a number of officials having to do with maintenance of way work and find without exception that they are of the opinion that the use of heavier power and increased tonnage is affecting their roadbeds to a great extent. It is noticed, however, that in the West it is doubtful if all roadbeds can be considered entirely stabilized, at least to the extent that they are in the East.

Your Committee has not as yet determined upon a method of procedure but feel that the subject is an important one and while they can now only report progress, that the subject should be reassigned them for next year's work.

Appendix E

(5) FILLING OF BRIDGE OPENINGS

J. C. Wrenshall, *Chairman;*
A. S. Butterworth,
G. L. Sitton,
C. E. Weaver,
Sub-Committee.

Preliminary Investigation

1. Before deciding whether or not to fill a certain structure, a thorough study of costs, based on local conditions, must be made, in order that preference be given to filling structures where the greatest saving in future maintenance may be effected. This applies in greater degree to wooden trestles. It is obvious that long, low structures, where the water can be carried by comparatively small culverts, will show the greatest saving. In the case of iron structures where operating conditions such as the use of heavier power demand replacement by solid fill and where commercial dirt and ashes are available in large quantities and at the expense of the haul only, other considerations than future maintenance should govern.

2. The preliminary investigation must develop especially:

(a) The size of culvert necessary, which will generally govern the type of culvert to be used. Emphasis is laid on providing sufficient area to carry off excessive storm water.

(b) The character of foundation available for the culvert. In order to determine the foot-ton carrying capacity of the soil, which will govern the design of the culvert.

(c) The character of foundation for the new fill. The nature of the foundation may be such that it would not be economical to fill the structure in question.

(d) The condition of the moisture with regard to withstanding the stresses incident to filling and carrying traffic at the same time; for if a trestle is allowed to deteriorate too far before filling, serious difficulties will be encountered in keeping the structure safe for traffic during the progress of filling.

(e) The availability and quality of material for making the fill, as both will affect the first cost, and the latter the future maintenance of the fill. Where commercial dirt is available in large quantities, consideration should be given to its character and the cost of the haul involved.

(f) Whether or not the advantage of widening adjacent cuts from which the filling material may be excavated will by improved drainage and increased snow room justify this method of procedure as against getting all the material from one place.

(g) Consideration should be given to the necessity of providing undergrade crossings to accommodate future as well as existing highways.

(h) Elimination of fire hazard by reason of filling wooden trestles should be taken into consideration.

Construction of Culvert

This phase of the work is not sufficiently different from ordinary culvert construction to require special emphasis except as follows:

(a) The culvert must be long enough. Care must be taken to determine at what slope the filling material will stand in order to insure construction of a culvert of sufficient length, which length should be determined by observation of the slope of the soil in question in other fills.

(b) The culvert must have a foundation suitable to the load.

(c) In preparing culvert foundation, care must be taken not to endanger the stability of the structure, by undermining or excavating too close to bents without proper protection.

(d) The culvert must be thoroughly protected against scour, due consideration being given to the susceptibility of scour, or the new filling material, and of the foundation material. This protection may be provided by the construction of ample head and wing walls; concrete aprons with curtain walls; and concrete floor which in extreme cases may require transverse ribs at intervals.

(e) Back-fill around and over culvert should be carefully placed so as to avoid unequal stress, and culvert should be protected from danger of damage by falling rocks during filling of structure. This protection may be provided by placing an earth cushion over culvert, but a cushion of one or two-man stone is preferable, for that provides future drainage from around the barrel of culvert as well as protection during the operation of making the fill.

Construction of Fill and Care of Structure During Filling

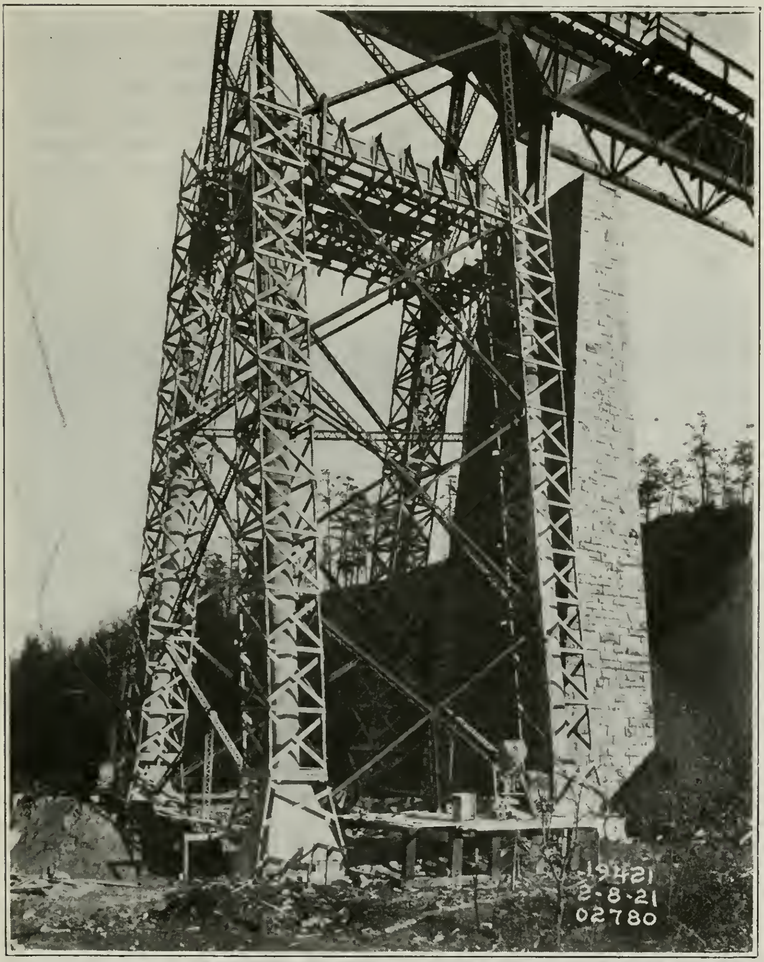
1. Before starting to construct fill, see if there are any springs in the area to be covered, and if so, build concrete boxes over same and pipe the water beyond the limit of the new fill, where rock is available

and fall is sufficient. French drains may be substituted for the pipe. In certain sections of the country where trestles are to be filled in marsh land, it is frequently found advantageous to lay a grillage consisting of a double layer of small tree trunks; the layers being at right angles to each other. In the absence of tree trunks, old bridge timber or sawmill slabs can be substituted. This grillage assists in preventing unequal settlement and excessive subsidence.

2. With wooden trestles, before starting new fill, the trestle must be carefully gone over and put in shape to stand the stresses incident to filling. This is very important, because if it is not done and trestle gets out of surface or line, or both, it is almost impossible to get it back to proper shape. While this item does not amount to much in a 10 or 12 ft. trestle, when dealing with a trestle over 20 ft. high, it is important. If this preliminary work is properly done, it is almost always possible to keep the structure in good line, although, of course, the entire foundation may settle and cause a settlement in the surface of the trestle. Such a settlement, however, is generally not a serious difficulty, as long as the line is good. Ordinarily, a foundation which is good enough to support a standard frame trestle will be found to give very little trouble during filling if a bearing 4 ft. wide is provided the full length of each sill. In this connection, special attention should be given to removing all soft timber from bottom of posts, from sills, and from bottom bracing, and sometimes additional posts. It is better to spend a little money preparing a trestle to stand filling than to take a chance of having to spend much more during the progress of the work. It has been found to be a fairly good rule to work by that in a trestle 20 ft. high the blocking sills, bottom of posts, and braces, should be in condition to run two years without repairs, and in a trestle 35 ft. high or over, three years, before the structure should be considered in good enough condition to stand filling.

(a) In the case of iron and steel viaducts which are usually of greater height than wooden structures, precautions must be taken to prevent distortion of the columns. This can be accomplished by encasing the columns in reinforced concrete up to a point within 20 ft. of base of rail, or where there is no danger from fire satisfactory results have been obtained by the erection of intermediate wooden bents at suitable intervals in order to reduce the load upon the towers.

(b) As the filling of the viaduct proceeds, all bracing, both longitudinal and transverse, should be cut loose from the bents as the fill reaches the connection points, for this bracing transfers a great deal of load to the bents, which increases the settlement and has a tendency to work the viaduct out of line. Vertical bracing need only be cut loose at the upper connection points.



View Showing Forming to Hold Molds for Pouring Concrete Around High Tower Columns, Stiffening the Columns to Resist Deformation During Filling

3. There are two methods in general use for filling bridge openings:

   1. By use of side or center dump cars, or both.
   2. By teams from adjacent cuts and borrow pits.
   3. By grab buckets swung from cable way.

In lesser degree:

   4. By endless belt conveyor.
   5. By dumping from cars and leveling by sluicing.
   6. By hydraulic excavation and leveling by sluicing.

4. Where foundation is good, and in case of low trestles, where it is not good, fills can be made by dumping directly from the structure to be filled. Good results may be obtained by use of a ditching machine in

View of Concrete Stiffened Columns After Forms Have Been Removed; Also Inverted V-Shaped Wooden Shields to Spread Filling Material When Center Dump Cars Are Used

conjunction with two 16-yd. air dump cars for jobs of approximately 5,000 cu. yds. or less, and by steam shovel and air dump cars for jobs of over 5,000 cu. yds., though this dividing line is by no means fixed, as it depends on the haul, the depth of cuts from which material is available, and the relative need for ditching the cuts in the vicinity of the structure. The double benefit derived from the use of a ditcher often justifies a greater total expenditure than would be involved in the use of a steam shovel.

5. Before dumping from trestle, wooden guard timbers should be removed and plank about 2 in. by 2 in. should be spiked on top of ties, close by rail, to prevent ties from bunching. This applies to side dumping. When center dumping is employed, the same method may be followed with the addition of cutting out alternate ties between the inside line of the stringers.

6. When dumping large rocks, care should be taken not to damage essential members of the structure. It is sometimes advantageous to install inverted "V" shaped wooden shields with comb located under the center line of track. This accomplishes a dual purpose; first, it affords protection to members which may otherwise be damaged by heavy filling

View of Filling Operations Involving Heavy Concrete Construction, Viz., Arch Over Highway and Trolley and Two Arches Over Stream. Note the High Drop of Filling Material: the Concrete Was Protected by Cushion of One or Two Man Stone Over Barrel of Each Arch.

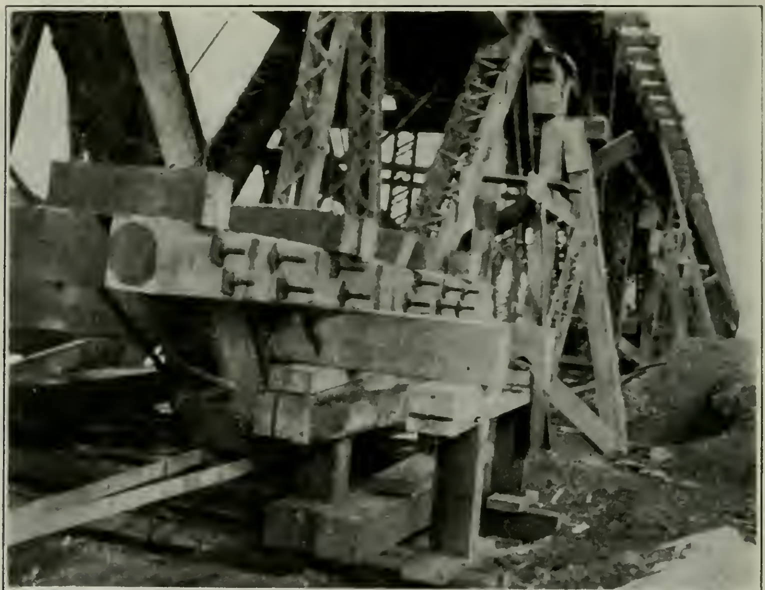
material from a high drop; secondly, this approximates to the side dump method which results in less disturbance to the structure. The shields must be removed when the filling has progressed so far that the dirt will not fall free of the shield.

7. When filling high trestles where foundation is very bad and appears liable to give trouble due to settlement, and traffic may be sufficiently heavy to justify it, it may be advisable to build temporary trestles on each side of the main trestle, say from one-third to one-half the height of main trestle, and located so that material dumped from same will spread to cover the area of the completed fill. The use of grab buckets from cable way or use of endless belt conveyor may be employed to advantage in making fills of this character. Then by dumping simultaneously from all three trestles, or dumping simultaneously from main

trestle and cable ways, the settlement may be reduced and kept fairly uniform.

8. It is often advisable to haul filling material further, in order to obtain a better grade of material to stabilize the fill and reduce cost of future maintenance.

9. Sufficient material should be deposited in fill to allow for shrinkage of embankment and subsidence of foundation. Fills made adjacent to and subject to erosion by rivers may be made more compact and repellent to water action by having the dirt spread by teams in layers over the entire area to be covered.



View of Saddle on Heavy Timber Grillage to Carry Ends of Deck Trusses After Fire in Fill Had Destroyed Supporting High Tower Columns.

10. It is considered good practice when filling trestles of over approximately 25 feet in height to install a small pump, if there is water available at the opening, and run a pipe line underneath the ties through the center of the trestle, having valves at intervals so that the trough formed by dumping on both sides of the trestle, or the central core when center dump cars are used, is kept continually wet. In this way settlement occurs gradually as the filling is deposited, with the result that the filled trestle is not carried so badly out of line and surface, but also when the fill is completed there is a solid puddle core from the bottom to the top to carry the weight of trains.

11. Immediately after the completion of the filling of low trestles, the stringers should be removed, but in cases of high trestles, the stringers should not be removed until the fill has settled about all it will without the load of trains; except that, if trestle has become so badly out of line and surface that it cannot be resurfaced and relined, it is better to remove the stringers at once and put the load on the green fill, even if this requires considerable watching and resurfacing of track for some time.

12. Care should be taken to avoid the formation of a trough which will hold water when removing stringers. This may be done by filling openings left by stringers with a good grade of clay, and tamping and crowning same before applying ballast.

13. On account of its cheapness, and ease of handling, track should be ballasted on engine ashes until new fill has entirely stopped settling.

14. Where engine ashes or commercial dirt is used for making fill, great care should be taken that the fill does not catch fire. When engine ashes are collected from water pits the fire hazard is very greatly reduced, but where cars are loaded from hot ash pits and the fires are not quenched by the ash pit shovelers, the cars should be run under the water plug in order that the live coals may be deadened. In handling commercial dirt, yard scrapings, shop cleanings, and filling of that general character, all paper, sticks, planks, greasy rags, oily waste, etc., should be removed during the unloading process, for if allowed to remain, spontaneous combustion will probably set in with disastrous results; particularly is this the case where live coals in the engine ashes become a part of the fill. On a large job of this kind it is always well to have a good sized force pump installed with sufficient fire hose to overcome fire, which may start in the fill when least expected.

15. It is recommended that in making fills of great height, or when unusual conditions are anticipated, that an Inspector with full authority be kept continuously on the work.

Filling by Hydraulics

16. Water is diverted from the most convenient mountain stream and carried along the mountain side parallel with the line of track and usually about 200 feet above same, from which it is taken for use in the hydraulic "monitor or giant" employed in this work. The jet used is from three to four inches in diameter, depending upon the amount of water available. The material is carried to the trestle in ordinary rectangular box flumes and the discharge outlet is varied from time to time to meet the requirements. The building of the levee is a special feature. It is usually constructed of alternate layers of earth and straw or hay, tough marsh grass is suited best for this purpose. The material is spaded from the inside and the hay is distributed by a man walking along the dike and shaking same down neatly. The next layer of earth compacts the hay and while this might appear to be quite porous, it is in fact very quickly puddled by the action of the water. The embankment

is usually constructed to within 3 or 4 feet of its finished elevation, and is then completed by train. Banks constructed in this manner are remarkably solid and subsidence is unusual other than that arising in some cases from the compression of the original soil on which it rests; also the hay or straw on the levee has the advantage of protecting the newly made bank not only during the first year but subsequently as the seeds germinate and form a sod. The cost of the process varies with the local conditions, but this method is very satisfactory in that there is no interruption to traffic by work trains during the greater part of the work. This method has been largely used on the Northern Pacific Railway.

Photographs of actual working conditions received from E. F. Gorman and C. W. McFarland.

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(6) THE RELATIVE ECONOMY AND ADVANTAGES OF VARIOUS METHODS OF DITCHING EARTH CUTS, CLEANING AND SHAPING ROADWAY DITCHES, ROAD-BED AND BALLAST SHOULDERS, WITH SPECIAL REFERENCE TO LABOR-SAVING DEVICES NOW IN USE, AND THE DEVELOPMENT OF MACHINERY FOR THIS PURPOSE

(10) METHODS OF PROVIDING OUTSIDE DITCHES FOR MAIN TRACK DRAINAGE WITHOUT UTILIZING THE MAIN TRACK FOR LOADING THE EXCAVATED MATERIAL

H. E. Tyrrell, *Chairman.*

W. H. Penfield, F. Ringer, *Sub-Committee.*

The Sub-Committee believes that these two subjects may be combined and properly considered together under the general term "Ditching."

Ditching on different railroads is done under many varying conditions; using practically the same method, the unit costs for work of like character vary about as follows:

Casting	$ .42 to $1.00	per cu. yd.
Company forces with wheelbarrow or push cars	.50 to 1.95	per cu. yd.
Spreader car	.09 to .175	per cu. yd.
Ditching machine	.04 to .722	per cu. yd.
Teams and scrapers	.50 to 1.37	per cu. yd.

These figures are derived from data furnished by less than thirty per cent of the railroads which have furnished information for the use of the Committee, and while they may have some significance, they are of little value in drawing conclusions without a complete statement of the conditions under which each job was done, as well as direct information as to what items were included in the costs and the methods of measurement. In other words, there is not unit costs data available except on individual railroads, and each railroad has its data in such shape that comparisons may be made on its own line, but it is impossible to compare it with other lines.

If on two railroads using the same method the unit costs of similar work vary more than one hundred per cent, as the data indicates, it is evident that either the units were not obtained in the same manner or the conditions under which the work was done were entirely different, even taking into consideration difference in rates of pay.

In arriving at conclusions it is, therefore, not practical to make the unit costs data the basis of such conclusions, but it is possible to draw conclusions from the general information furnished and to cite from such information which method is most economical under several sets of varying conditions. It is believed that conclusions so drawn will be of more value in determining the method to be used in any particular case than unit costs figures based on unknown conditions which might be entirely different from the case in question.

Methods

(1) Company Forces: Section labor, extra gang labor, or other regular employes subject to the regular direction of the Supervisors or other corresponding subordinate officers, with or without work train.

(2) Station Men: Work done by hand labor with shovels and wheelbarrows under contract on yardage basis.

(3) Teams and scrapers on force account or yardage basis.

(4) Auxiliary track and small cars: Where width of cuts and roadway permits a narrow gauge track is laid through the cut and to the spoil banks permitting small cars to be handled either by man power, teams or small gasoline mule. This is done either by contract or with company forces.

(5) Spreader car equipped with wings for shaping ballast shoulders, roadbed shoulders, ditches and slopes: These machines must use the tracks and entail the use of a locomotive and train crew. The material which they handle being either pushed to the end of the cut or over the top.

(6) Ditching machines: Machines known under this designation are numerous, but for the purpose of this report all machines designed for, or adapted to, excavating material, loading it on cars, or carrying it from one point to another, are included. It is not intended to include spreader cars equipped with ditching attachments, or ditching equipment which is used in the nature of a plow; nor is it intended to include steam shovels.

The most widely known ditching machine is, no doubt, the steam ditcher. There are several types of this machine and they are generally operated in a work train, the machine being set on top of a flat car, the equipment consisting of ditching machine, one dump car located at each end of the machine, spreader car and locomotive. They are also arranged to work over a train of flat cars and load one after another, backing up as they load. They may, if work requires, be removed from their flat cars and operated without a locomotive as they are self-propelled.

Another type of ditching machine not so generally recognized as such is the locomotive crane equipped with a one or one and one-half cubic yard clam-shell bucket. This may be operated in a train with dump cars at either end or under its own power with or without cars. In either case two laborers are necessary to properly place bucket in order to cut a uniform ditch.

The third type of ditching machine could be classed as scoop ditchers and would include those machines which do not operate under their own power, but have scoops or buckets, usually operated by compressed air, and so arranged that they are filled by the movement of the train, and the material is either carried out of the cut in the scoops, or is loaded on flat cars by means of an auxiliary hoisting engine and cables.

CONCLUSIONS

(1) Good roadbed drainage is the foundation of economical track maintenance; therefore, the ditching of cuts is of great importance and should be carried out currently with the regular yearly maintenance program.

(2) Ditching, in ordinary material, may be subdivided into two principal classes:

Class "A"—Cuts not more than six feet deep in average open counter.

Class "B"—Cuts more than six feet deep.

Class "A"—Cuts Less Than Six Feet Deep

(3) Company forces: On lines where traffic is heavy and ditching is done currently the work can usually be done economically by company forces, the material being cast out of the cut and leveled back so as to prevent it from washing down into the ditches. This method may also be economical on lighter traffic lines, where cuts are isolated and the volume of material to be moved is comparatively small.

(4) Contract forces; station men; teams and scrapers: These methods are found to be economical on lines of heavy traffic where, on account of deferred maintenance or nature of material, the volume to be handled is large. These methods may also be used to advantage on lighter traffic lines where conditions are favorable. In all cases where material is deposited on top of the cuts it should be leveled back to prevent washing down into the ditches.

(5) Spreader cars equipped with wings for shaping ballast shoulders, roadbed shoulders, ditches and slopes: These machines may be used to advantage on lines of moderate traffic in ordinary material, but their use is not recommended on heavy traffic, single track, lines with frequent trains; nor is the use of other ditching machines recommended under similar conditions.

Class "B"—Cuts More Than Six Feet Deep

(6) Company forces provided with push cars and dump beds, wheelbarrows or trackbarrows. Loading and hauling out: This method will be found to be economical on heavy traffic lines, and also on lines with moderate traffic, where ditching machines are not available, or where the volume of material to be handled would not justify their use.

The use of work trains with hand labor is generally uneconomic, and is not recommended.

(7) Teams and scrapers on yardage basis: Where the character of material is suitable, and the volume to be handled comparatively large, teams and scrapers may be used to advantage under unit cost contract provided the cuts are of sufficient width to permit of safe operation.

(8) Auxiliary track and small cars: This method may be used economically on heavy traffic lines where operating tracks cannot be interfered with and where there is sufficient clearance, provided the haul is long and volume of material to be handled would justify the initial cost of the plant installation.

Ditching Machines

(9) There are a number of items and conditions which should be considered before undertaking work with ditching machines and their equipment—interest on investment, depreciation, upkeep, work train service and interruption to traffic are vital items which should not be overlooked. Equipment of this class has advantages which should also be taken into consideration. Ditching machines have a wide scope of operation; they will move large volumes of material in a comparatively short time; they make it practicable to utilize the material excavated for bank widening, trestle filling or other like work. The final consideration relative to use of ditching machines is the density of traffic or frequency of trains.

The use of steam ditchers and their equipment is recommended in work where the cuts are long and deep, or where the volume of material to be moved is great; or where the material is wet and difficult to handle by other methods. Their use is also recommended where cuts are resloped or widened to such a limited extent as *not* to justify the use of steam shovel. Under similar conditions they may be used for widening embankments. They are particularly efficient in removing small slides or other like emergencies where material is wet or hard to handle.

Locomotive cranes equipped with clam-shell buckets one to one and one-half cubic yards capacity can be used successfully in cleaning out cut ditches where it is desirable not to disturb the slopes and will produce a ditch of uniform width and depth without handling surplus material or requiring any redressing by hand. On account of the possibility of a considerably longer boom, this machine is more elastic in disposing of material, as it will even deposit material above grade on top of cut of medium depth. Under favorable circumstances it may be used without work train service, as it is self-propelling. Also, on account of the long boom, when equipped with orange peal bucket, this machine can be used to advantage in cleaning out coarse material from cross ditches.

Where, on account of long haul in disposing of material, it is necessary to load many cars before dumping ditching equipment is recommended which will operate over a series of flat cars with a proper mechanical device or plow for unloading.

There may be isolated cases where it is economical to use scoop ditchers, but it is believed the steam ditcher or the locomotive crane will accomplish the same results with a greater flexibility.

(10) Work incidental to ditching such as shaping roadbed and ballast shoulders is primarily hand work after the major work of ditching is complete, but by the use of spreader cars with proper attachments this work may be done at a cost that is comparatively very low and their use is recommended for these purposes when the nature of material will permit and where traffic conditions are not such as to prohibit such interference.

Appendix G

(7) CHEMICAL KILLING OF WEEDS ON AND REMOVAL OF KILLED WEEDS FROM THE ROADBED

S. B. Fisher, *Chairman;* R. A. Rutledge,
A. A. Matthews, *Sub-Committee.*

Inasmuch as this Sub-Committee has worked under the belief that the application of chemicals to weed killing has only been recently initiated, and of rather limited use by some of the railways and trolley lines in our country, no general circular asking for data and information has been sent out; but the Committee has tried to obtain information by personal solicitation and letters to officers of the railways who have had charge of the work, and were thus in position to give facts and reliable data on this new subject. As there has seemed to be a partial or total reluctance to respond on the part of some from whom information was asked—the data thus obtained this year is not as full as your Committee would desire, although responses by some were prompt, full and valuable.

We have also been in communication with supply and contracting parties who very kindly gave us copious information on both the chemicals and their application and their views of the results which have been and can be obtained from the application of chemicals to weed destruction.

The second part of the subject, the removal of killed weeds from the roadbed, was at first considered eliminated as the uniform testimony received was to the effect that the wind and train suction automatically removed the weeds from the roadbed, but lately cases are reported from California, where some of the weeds grow all the year and from Texas, in which it was considered advisable to run a weed burner over the road to burn the weed stalks after they were chemically killed, or to clean the track by hand.

Chemical weed killing was first initiated in 1906 by Dr. Ortin of Galveston, Texas, and a limited success in a restricted area of application was attained by him, but he was not able to carry it to a commercial success. Confining our statements to present reports chemical weed killing was started in 1912 and 1913, with a few roads treating moderately long stretches of track. The war interfered with its progress like it did with other work, but since then during the last few years it has been resumed and is now being followed rather vigorously, thousands of miles of railway and trolley lines being treated each year, so far in yearly increasing mileage. One contracting company has at the present time seven trains equipped for this work. The scarcity and high rate of labor has, no doubt, stimulated this method of weed killing.

The chemical mostly used, so far as found out, is a mixture or compound of Arsenic and Caustic Soda, using 8 to 10 per cent of the latter by weight, dissolving the solid chemicals in water. The chemical is shipped in accordance with needs or demands in cans, barrels, drums or tank cars, in concentrated form, and diluted with water at the place of application, as circumstances require, which is usually one part of the concentrated chemical to 18 or 20 parts of water, with the arsenic-caustic soda combination referred to above. The application is made on any desired scale from a hand car, single flat car, or entire train, all with proper equipment. The fully equipped train is the only method with which to work economically on a large scale. The train is made up of 6 or 8 cars. The front or pilot car of the train contains the sprinkling apparatus, composed mainly of pipes, perforated with small holes or nipples for the emission and diffusion of the poisoning liquid, valves, meters, etc., all under the complete control of the operator. In the same car are pumps and air compressor actuated preferably by motors of Marine type, to furnish pressure to the liquid, in applying it to spraying the weeds, and to furnish compressed air for mixing the diluting water with the concentrated chemical. The liquids are thoroughly mixed by means of compressed air before application.

In the after part of this car may be living quarters for the crew. The main part of the train is made up of tank cars—all connected together with lines of pipes, and fully supplied with valves, meters, all necessary appliances. One of these tank cars is loaded with the concentrated solution which is drawn out as needed. The other tank cars carry a supply of the chemical diluted to the strength for spraying on the weeds. The last tank car contains Repellant, a liquid to be sprinkled over the weeds after the poison has been applied at road crossings, station grounds, etc., in places where cattle are liable to browse on the vegetable growth and be poisoned by the compound. This Repellant is bitter or contains something disagreeable to grazing stock, this however appears to be of doubtful value. Last of all comes the locomotive pushing the trains. Before starting to sprinkle—the tank cars carrying the diluted mixture are filled. The concentrated chemical is drawn from its storage car and mixed 14 to 20 parts more or less of water as practised by the company with largest equipment and doing most treatment on the roads, while another company dilutes with equal volumes of concentrate and water. Thus the amount of dilution must be determined in each case from the strength of the solution and the vigor of growth and thickness of the stand and kind or species of weeds to be killed.

The volumes are measured by meters and gages. The tank cars ought to contain enough liquid to reach to the next water station, 20 miles or more. The solution is applied at a speed of about 20 miles per hour, and by following a freight or local train as a second section, there is no interference with traffic. When the next water station is reached, a stop of an hour is made—although half an hour is usually long enough to refill the empty tank cars with another supply.

The rate of application in volume per unit of area varies according to condition as much or even more than the strength of solution. A very convenient unit of measurement is gallons of solution per foot of width per mile of roadbed, which appears to be ordinarily within the limits of 5 and 15, or a minimum application of 5 gallons for width of 8 feet will take 40 gallons per mile, while a maximum application of 15 gallons per foot for 14 feet width will take 210 gallons.

The rate of spraying per unit of surface is regulated either by controlling the amount of liquid allowed to escape from jets, which can be made under the control of the operator, or by varying the speed of the train or by both means. The rate of emission should be directly proportional to the weed growth and must be controlled by the judgment of the operator.

It is claimed by some roads using the chemical weed killer that the weeds should be allowed to attain their full growth before application, so that the sap in descending the stocks will carry the poison to the roots. Others claim that the chemicals should be applied to the growing weeds in order to eliminate them from the roadbed during the summer season. It should be applied before cutting the weeds, as cutting causes the weeds to seal over the cut, preventing the poison penetrating to the roots.

It should not be applied immediately after a rain as the cells of the weeds will be full of water and prevent much poison entering. It is claimed in some reports that the chemicals should not be applied immediately before rain, as rain washes the solution away so it will not enter the plant. It is claimed by others that rain after application is beneficial, because the solution being dried, is redissolved by the rain and is then absorbed by the plant.

It is claimed by the advocates of chemical weed killing that successive application in lessening quantities per year for three years will completely extirpate the weeds, and the only ones afterwards growing will come from seed blown or carried in on the right-of-way. It is also held that the ground may be completely sterilized by the chemicals so it will grow weeds, but no instance of it actually being done has been given. Only one case has been reported so far of complete killing of weeds after three years' application. Some reports indicate that the most effective method is to make the first application so strong that all the weeds are killed—that successive weak applications tend to make the weeds immune. Some grasses and weeds, such as Johnson, Burmuda, Salt, Blue Stem, Wire, Crab Grasses, Horsetail, Ragweed and Bull Thistle, do not appear to be killed by a single application, and their complete destruction is still a problem.

One road reports that after four years' application it was decided to discontinue entirely the use of the weed killer and resort to the weed burner, claiming that the "weed killer" did not destroy all the weeds and those that did succumb were dried and left to foul the ballast and otherwise giving an unsightly appearance to the roadway, and also that the cost was far in excess and also the results less satisfactory with the weed killer than with the weed burner.

Attention is directed to the application of common salt to weeds on 454 miles of the Erie Railroad, as reported by Mr. I. H. Schram, Regional Engineer. The salt was applied from the car by shoveling on chutes which made the distribution in work train service at the rate of eight-tenths car loads per mile. The cost was for labor and train $13.40 per mile, for foreign freight $18.75, total $32.20. The cost of hand weeding in that district has been $73.33—which gives cost of salt application 44% of cost of hand weeding. The salt was good mined salt, but rejection from crusher account being too coarse for market, and was received without cost. Approximately 40 tons per mile was used. The application was very effective and killed all the weeds. In this part of New York, in the vicinity of Rochester, salt has been used for a number of years for weed killing. Care, however, must be exercised in its application to prevent interference with automatic signaling.

Summary of Data Received

			Per Mile			
Road	*Date*	*Miles*	*Gals.*	*Cost*	*Solution*	*Remarks*
Balt. & Ohio...	1912	20				
Balt. & Ohio...	1918	565	34.8	25.73		
South. Pacific...	1920	2000	92.5		1:20	1920 and later
South. Pacific...	1918			65.00		First treatment
South. Pacific...	1918			35.00		Second treatment
South. Pacific...	1919			61.00		First treatment
South. Pacific...	1919			22.00		Second treatment
Illinois Central..	1920		75	63.00	1:12&20	
Frisco.	1921	175	129	115.00	1:12&20	First treatment
M. K. & T......	1919	20				
M. K. & T......	1920	245	96.1	81.91		
Santa Fe........	1919	309		75.55		G. C. & S. F.
Santa Fe........	1920	350		91.80		Western Lines
Santa Fe........	1921	171		95.54		Southern District
Santa Fe........	1921	95		88.60		Plains Division
Santa Fe........	1921	26		113.00		Dayton Division
Southern Ry....	1914	685	112	40.29		May and June
Southern Ry....	1915	1011	85	30.45		June, July, August
Southern Ry....	1916	1058	50.8	27.76		August, September
Southern Ry....	1917	523	57.8	28.89		August, September
Union Pacific...	1916	76.6		38.30		
Union Pacific...	1917	158.3	102	59.77		
Union Pacific...	1918	147.4	101	73.20		
Union Pacific...	1919	119.1	81	59.40		
Union Pacific...	1921	694.4		16.44		Weed burner

Manufacturers Distribution of Cost

Chemical	$0.60075
Manufacturing	0.053
Sprinkling	0.1205
General Expense.......................	0.0416
	$0.81585

CONCLUSIONS

Your Committee does not believe it has as yet enough data to report definite conclusions. It has many favorable reports of successful application and some of unsuccessful, or at least unsatisfactory ones. The reports nearly all cover only one year's work—the results of at least three successive applications ought to be definitely known before framing conclusions. The railroads that have been using it are generally continuing it on a yearly enlarged program, although a few have discontinued.

There are cases where the contractor has been asked to do the work over again account unsatisfactory results in first application. How much this is due to unfavorable circumstances and how much to the system itself has not yet been ascertained. The reports so far received indicate that a very large percentage of the soft annuals or tender weeds are killed by the first application—running in many cases up to 85 or 95 per cent, but a smaller proportion of perennial and hardier annuals only are exterminated; about 50 per cent more or less so far as reported.

The Committee can only report considerable work done and little progress for the past year, and would recommend a continuation of the study—as several roads are now gathering information which will be of value on the subject for future report.

Appendix H

(8) DESIGN AND USE OF REINFORCED CONCRETE CULVERT PIPE

W. C. Curd, *Chairman;* H. B. Robinson,
R. C. Gowdy, *Sub-Committee.*

Your Committee has consulted with the Masonry Committee and are advised the above subject was assigned them in 1917. Progress reports and tentative specifications have been submitted by that committee and will be found on pages 748 to 762, Vol. 19, and pages 697 to 701, Vol. 20 of the Proceedings of this Association.

In 1919 the Masonry Committee reported that "while progress has been made they feel that further investigation as to the distribution and transmission of pressures from engine loads and earth fills is necessary before a conclusion can be reached."

Other Societies, having the same subject also under consideration, appointed a Special Committee in 1920, composed of two members from each of the following societies:

American Society of Civil Engineers.
American Society of Testing Materials.
American Concrete Institute.
American Highway Association.
American Concrete Pipe Association.
American Railway Engineering Association.

This Special Committee met the same obstacle—the lack of information concerning earth pressures and pipe loading—and are now awaiting results of experiments at Iowa Agricultural College before reporting, which experiments will probably require another year to complete.

Your Committee has confined its investigation to the application of reinforced concrete pipe and finds it of general use among railways. The majority of the roads prefer to purchase under approved specifications from reputable manufacturers rather than to attempt its manufacture.

It is reported that the principal advantage is its cost, particularly under war conditions, when it could be obtained at a figure greatly under that quoted for cast iron.

The greatest objection to its use is the excessive weight of the individual piece, chiefly in the large diameters, which often necessitate work train and derrick for placing, thus increasing the cost.

Preference is expressed for the circular section rather than for oval section, as in many cases the oval section has been laid with flat side down, which resulted in failure. The circular section, properly designed and manufactured, eliminates this difficulty.

Some favor pipe culverts only at unimportant openings and limit the maximum diameter to 36 in., as above that size a concrete box, affording a greater waterway, may be constructed at practically the same or less cost.

Your Committee concludes that where cost and other essential items are equal, there is no particular advantage in using reinforced concrete pipe in preference to other approved forms of culverts.

In view of the joint investigation of the subject now under way by a Special Committee of other societies, your Committee recommends the Masonry Committee be permitted to conclude the subject for this Association at such time as may be proper, and that your Committee be relieved of the subject.

Appendix I

(9) THE EXCESSIVE COST OF MAINTENANCE DURING THE EARLY PERIOD OF OPERATION

C. C. Cunningham, *Chairman;*
R. C. Gowdy,
F. Ringer,
W. M. Jaekle,
W. H. Woodbury,
Sub-Committee.

There has been considerable amount of thought spent on the part of the various engineers of the various railroads of the United States relative to the question of the increased cost of maintenance of roadway and track during the early periods of operation of newly-constructed lines.

This question involves a good many factors and must be carefully studied as it is applied to railroads built in different localities.

In order to develop information as to whether the cost of maintenance is greater during the early periods than it is during the later periods of operation one must necessarily compile cost data for two lines of railroad which the length and physical conditions are essentially similar. The new lines should be compared with a line which has been in operation under similar traffic for a period of several years and where the track and roadbed have become fairly stabilized.

The physical and topographic conditions vary so greatly in different parts of the country that this is a subject which has to be approached with a great deal of care as in many places it would be difficult to find two lines of railroad which are closely comparable.

When determining the difference in cost of maintenance during the early period of operation of one line with another, one should also take great pains to see that the methods and standards followed in construction are approximately identical. One should not attempt to compare a line built for Class A, main line traffic, and one built to handle secondary or branch line traffic.

If the natural surface and the soil is of a stable nature one would be lead to expect that if the new roadbed were well built that the early cost of maintenance due to the solidification of the roadbed would not be excessive. However, a comparative study might introduce either elements which would make a change.

A number of railroads have been compiling data in order to develop this information but their study has not as yet reached a concrete form. For the consideration of the members of the Association we are submitting Forms "A" and "B," which may prove of value in a study of the subject.

The methods now in vogue on different railroads in compiling cost of maintenance in compliance with the instructions of the Interstate Commerce Commission are of sufficient extent to enable one to arrive at a correct result, provided these methods are followed intelligently.

STUDY OF EXCESS MAINTENANCE COSTS INCIDENT TO SOLIDIFICATION AND SEASONING OF ROADBED AND TRACK

Form A

Sub-Committee's Exhibit No.................
Carrier ....
Line from...............To.................
Main or Branch...........State.............
Carrier's Exhibit No.......................
Sheet.........of.........Sheets.

Description of Line

Characteristics of Line:
Miles of First Main Track......: Second Main......: Third Main......: Fourth Main......: Other Tracks......:
Total..........
Roadway Miles in cuts......: Roadway Miles on fills......: Roadway Miles on bottoms or overflow land.......
Average depth of cuts......: Average height of fills......: Maximum Grade....: Length of Maximum Grade.......

Topography of Country Traversed:
Low Swampy, River Margin, Valley, Rolling, Prairie, Plains, Hills, Plateau, Desert or Mountains. Is line with or across drainage or on ridge?

Supporting Power of Natural Surface as Foundation for Roadbed and Track:
Solid or soft, stable or unstable? Have slides or subsidence occurred and if so to slight or heavy extent?

Soil:
Silt, Clay, or Loam? Sandy Silt, Clay or Loam? Sand, Gravel, Loose Rock, etc.?

Climate:
Approximate average annual frost period in months...... Approximate average annual rainfall in inches..........
Temperature range..........to..........

Ballast:
Approximate average present depth of ballast on fills in inches under tie........ In cuts in inches under tie........
Is depth of ballast uniform or irregular on fills?.......... In cuts?..........

Grading:
Where original yardage and costs can not be ascertained, show the estimated quantities and reproduction costs reported by the Bureau of Valuation.
Report quantities and costs for the full line under study, omitting clearing, grubbing, bank protection work and covered drains.
Original or estimated reproduction cost............ (Give original costs; if obtainable.)
Com. cu. yds............. Total cost............ L. R. cu. yds............. Total cost............ S. R. cu. yds............. Total cost............ Other materials, cu. yds............. Total cost............

Remarks: Other Characteristics or Local Conditions Which May Have Influenced Maintenance.

Characteristics of Line Used to Develop Normal Costs, if Separate Line was Used.
Line from...........to...........State.............: Date opened for operation.........................
Miles of First Main Track......: Second Main......: Third Main......: Fourth Main......: Other Tracks......
Total..........

STUDY OF EXCESS MAINTENANCE COSTS INCIDENT TO SOLIDIFICATION AND SEASONING OF ROADBED AND TRACK

FORM B

COMPARISON OF CHARGES INCIDENT TO SOLIDIFICATION AND SEASONING OF ROADBED AND TRACK ON NEW AND SEASONED LINES.

LABOR RATE: ____________

SUBCOMMITTEE'S EXHIBIT NO.____________
CARRIER____________
LINE FROM____________TO____________
MAIN OR BRANCH____________STATE____________
OPENED FOR OPERATION____________
CARRIER'S EXHIBIT NO.____________
SHEET________OF________SHEETS________

	PERIOD															
EARLY PERIOD ON NEW LINE.	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year	8th Year	9th Year	10th Year	11th Year	12th Year	13th Year	14th Year	15th Year	TOTAL
Acct. 202 - Roadway Maintenance																
(A) Care of Roadway																
(B) General Cleaning																
(C) Watching Roadway																
(D) Bank Protection																
Acct. 220 - Trk. laying & Sfing.																
(E) Track Maintenance																
TOTAL																
	PERIOD															
SEASONED (NORMAL) LINE OR PERIOD.	1st Year	2nd Year	3rd Year	4th Year	5th Year	6th Year	7th Year	8th Year	9th Year	10th Year	11th Year	12th Year	13th Year	14th Year	15th Year	TOTAL
Acct. 202 - Roadway Maintenance																
(A) Care of Roadway																
(B) General Cleaning																
(C) Watching Roadway																
(D) Bank Protection																
Acct. 220 - Trk. laying & Sfing.																
(E) Track Maintenance																
TOTAL																
Excess Maintenance during Early Operation.																

Remarks:

REPORT OF COMMITTEE XVI—ECONOMICS OF RAILWAY LOCATION

A. S. GOING, *Chairman;*
F. H. ALFRED,
R. N. BEGIEN,
C. T. DELAMERE,
W. A. JAMES,
FRED LAVIS,
E. C. SCHMIDT,
A. K. SHURTLEFF,
C. W. STARK,
WALTER LORING WEBB,
M. A. ZOOK,

H. R. CARPENTER, *Vice-Chairman;*
WILLARD BEAHAN,
J. C. BEYE,
A. S. CUTLER,
E. E. KING,
E. H. MCHENRY,
H. C. SEARLS,
C. H. SPLITSTONE,
J. G. SULLIVAN,
J. W. WALTER,

Committee.

To the American Railway Engineering Association:

Your Committee on Economics of Railway Location reports progress on the subjects assigned to it, as follows:

(1) Revision of Manual

No changes in the Manual are proposed at this time.

(2) Effect of Curvature on Cost of
(a) Maintenance of Way, and
(b) Equipment

The Committee has reached the conclusion that it is difficult to present information on this subject that would be of practical value. It would be possible to work out results for a larger number of factors at the end of extended research, tests and experiments; but the practical value of such results would be doubtful. It would be practically impossible to reconcile the conclusions that might be reached with the practical conditions of operation. For these reasons, it is the recommendation of the Committee that this subject be dropped.

(5) Study and Revise to Date the Subject of Railway Locomotive Power

The Sub-Committee assigned to this subject is making a study of locomotive tractive effort and the various processes proposed for predicting tractive effort at various speeds, in the expectation of revising the present section on "power" in the Manual, where necessary. When conclusions concerning methods for estimating tractive effort have been arrived at, it is the purpose of the Sub-Committee to test their correctness by comparing calculated tractive effort with the tractive effort actually attained in service, determining the latter by means of a dynamometer car.

This work could not be completed in time for presentation with this report. It is therefore recommended that the subject be continued for the ensuing year.

(6) Methods of Estimating Power, Speed, Time and Fuel Consumption

The Sub-Committee assigned to this subject has only been able to formulate a procedure of study of the topic. It hopes to be able to submit the result of its study at the next annual meeting, and recommends that the subject be continued.

Recommendations for Future Work

(1) Report on the Economics of Railway Location as affected by the introduction of electric locomotives.

(2) Report on suitable units for comparing costs of maintenance of way, equipment and transportation.

(3) Study and revise to-date subject of railway locomotive power.

(4) Study and report on methods of estimating power, speed, time and fuel consumption.

Respectfully submitted,

The Committee on Economics of Railway Location,

A. S. Going, *Chairman.*

PROGRESS REPORT OF SPECIAL COMMITTEE ON STRESSES IN TRACK

To the American Railway Engineering Association:

The Special Committee on Stresses in Track, co-operating with a similar committee of the American Society of Civil Engineers and the American Railway Association, presents the following report of progress:

The principal work of the year 1921 has been the reduction and correlation of the data of the field tests made in 1920. It will be recalled that tests were conducted on the tracks of the Illinois Central Railroad in Illinois, the Delaware, Lackawanna & Western Railroad in New Jersey, and the Atchison, Topeka & Santa Fe Railway in New Mexico and Iowa. These tests were made on tangent track and curved track, several different curvatures being used. A principal purpose of the tests was to find the effect of curvature of track upon the stresses in the rail (including lateral bending stresses) caused by locomotives of different types run at different speeds, as compared with the stresses developed in straight track. The time required for the reduction of the large amount of data accumulated in the tests has been much greater than was anticipated. The work has been carried on steadily, however, and good progress has been made. It is hoped that the Committee will be able to present another report during this year. The results found indicate that information of value on stresses developed in curved track may be expected. Another line of work carried on is the investigation of rail joints. Laboratory tests have been conducted with various types of rail joints, the purpose of the tests being to find the way in which the joints act and to learn the magnitude of stress developed in the various parts of the rail joint at ordinary wheel loads—a type of investigation that it is believed has not previously been attempted. A few field tests have been conducted on the Illinois Central Railroad to connect up the laboratory tests with the action of the joint in the track under wheel loads. Interesting results have been developed in the rail joint tests.

The Committee has a number of other questions under consideration.

Respectfully submitted,

THE SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK,

A. N. TALBOT, *Chairman.*

REPORT OF COMMITTEE XI—ON RECORDS AND ACCOUNTS

H. M. Stout, *Chairman;*
Henry Lehn, *Vice-Chairman;*
A. M. Blanchard,
H. Bortin,
H. A. Campbell,
Armstrong Chinn,
R. A. Cook,
E. B. Crane,
E. B. Fithian,
J. H. Milburn,
W. F. Ogle,
H. J. Sargent,
H. F. Sharpley,
Chas. Silliman,
C. W. Simpson,
T. H. Strate,
W. A. VanHook,
V. R. Walling,
W. D. Wiggins,

Committee.

To the American Railway Engineering Association:

Your Committee on Records and Accounts respectfully submits report on the following subjects:

(1) Revision of the Manual

Proposed changes in the Manual are given in Appendix A.

(2) Cost-Keeping Methods and Statistical Records

The Committee submits a progress report on this subject in Appendix B.

(3) Forms for Recording Data for Keeping Up to Date Records of Property Changes and Valuation of Railroads

The Committee submits a progress report on this subject in Appendix C, and its recommendations are given under Conclusions.

(6) Conventional Signs for Architectural Details

The Committee submits a report of its work on this subject in Appendix D, and its recommendations under Conclusions.

(7) Methods for Recording and Accounting for the Determination of Proper Allowances for Maintenance of Way Expenses Due to Increased Use and Increased Investment

A sub-committee of this Committee has begun the study of this subject with a sub-committee of General Committee XXI—Economics of Railway Operation, but no results are ready for presentation to the Association this year.

The Committee also reports progress on subjects (4) Study and report on the feasibility of reporting engineering data in graphic form and sumbit recommended diagrams; (5) Study and report on the feasibility of reducing the number of forms used in the Engineering and Maintenance of Way Departments, combining forms and simplifying those retained.

Under Recommendations for Future Work is given the Committee's conclusions on (8) Recommend a carefully considered outline of the work for the ensuing year.

A

CONCLUSIONS

1. The Committee recommends that changes in the Manual, as submitted in Appendix A, be approved and the revised matter be substituted for the present subject-matter in the Manual.

2. The Committee reports progress on the subject of cost-keeping methods and statistical records, and recommends that it be reassigned.

3. The Committee submits three forms, shown here as Exhibits A, B, and C, revisions of those offered last year, and recommends their adoption and publication in the Manual. Appendix C also covers progress report, and the Committee recommends the continuation of the subject.

4. The Committee has under study the subject of the feasibility of reporting engineering data in graphic form and recommends that it be reassigned.

5. The Committee reports progress on the subject of the feasibility of reducing the number of forms used in the Engineering and Maintenance of Way Departments, combining forms and simplifying those retained, and recommends that it be reassigned.

6. The Committee recommends the adoption and publication in the Manual of the Electrical Symbols given under Exhibit D and that the Architectural Symbols shown under Exhibit E be accepted as information and the subject continued.

7. The Committee reports progress and recommends reassignment of the subject of methods for recording and accounting for the determination of proper allowances for maintenance of way expenses due to increased use and increased investment.

Recommendations for Future Work

For next year's work your Committee recommends the continuation of the first seven subjects.

Respectfully submitted,

The Committee on Records and Accounts,

H. M. Stout, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

Definitions.

ACCOUNT. (Present text)

A Statement required to enable payment to be made for labor performed and material furnished or to establish the detail, total and comparative cost of work and various classes of expenses.

ACCOUNT. (Revision)

A Statement required to enable payment to be made for labor performed, material furnished or to establish the detail, and total cost of work or class of expense.

LEDGER ACCOUNTS. (Present text)

Statements kept in ledger form in order to establish the detail, total and comparative cost of individual pieces of work or classes of expenses.

LEDGER ACCOUNT. (Revision)

An account of an individual piece of work or class of expense kept in ledger form.

Appendix B

(2) COST-KEEPING METHODS AND STATISTICAL RECORDS AND EMBRACING THE SUBJECT OF FORMS FOR ANALYZING EXPENDITURES FOR ASSISTANCE IN CONTROLLING EXPENDITURES

H. BORTIN, *Chairman;* E. B. FITHIAN, W. F. OGLE, H. J. SARGENT, W. A. VANHOOK, *Sub-Committee.*

When your sub-committee reported progress last year it had hoped that the railroad conditions which have a bearing on our subjects would so improve as to make a final report this year desirable and practicable.

Shortly after the March, 1921, convention a start was made by the Chairman and one of the near-by members of the Committee toward outlining a program for the preparation of a final report, but it soon became apparent that under the existing railroad situation your sub-committee could not do justice to its subject if it prepared and submitted a final report this year.

At a meeting of the sub-committee on July 11, 1921, which was attended by the full membership of the sub-committee (except one), as well as by the Chairman of the main Committee, and also at a subsequent meeting on September 7, 1921, it was the unanimous opinion that a final report, such as was planned in the 1919 *Report of Fundamental Principles,* could best be prepared *after* the existing railroad situation became more stabilized.

The changing conditions and requirements in cost-keeping methods and statistical records and in forms for controlling expenditures which were brought about, first, by Government control and operation of the railroads, then, by the return to private operation, and later, by the provisions of the Transportation Act with the various accounting problems which each of these developments introduced, together with the fact that various official committees of the railroads, the Interstate Commerce Commission, etc., are now developing much data that would be helpful and necessary to embody in the final report of this sub-committee, all these and other practical conditions dictated to the sub-committee the necessity of postponing a final report.

It is the agreed plan of this sub-committee to keep in touch with the data and progress made by the various official committees of the railroads and the I.C.C., who have charge of the collection and compilation of data pertaining to operating expense standards and to other features which bear on our subjects.

With this data soon available, together with data and forms representing the current practice and experience of representative individual railroads, this sub-committee expects to have sufficient information to illustrate and apply concretely the following principles of its preliminary report of 1919 by which the value of all forms, cost-keeping methods and statistical records may be tested:

1.	Should be **for a purpose**	6.	Should be **accurately compiled**
2.	" " **a record of facts**	7.	" " **economically assembled**
3.	" " **immediately available**	8.	" " **periodic**
4.	" " **easily understood**	9.	" " **comparable**
5.	" " **uniformly based**	10.	" " **properly used**

Appendix C

(3) FORMS FOR RECORDING DATA FOR KEEPING UP TO DATE PROPERTY CHANGES AND VALUATION OF PROPERTY OF RAILROADS

HENRY LEHN, *Chairman;* E. B. CRANE, H. F. SHARPLEY, CHAS. SILLIMAN, T. H. STRATE, *Sub-Committee.*

The following three forms were submitted to the Association last year as information: (a) Detailed Estimate Sheet to accompany and supplement the Authority for Expenditures, (b) Register of Authorities for Expenditures, and (c) Equipment Completion Report.

These forms have been given further study this year, resulting in some changes to the first two. The forms as now presented are here shown as Exhibits A, B, and C. They are recommended for adoption.

North & South Railroad

A.F.E. No. ________

DETAILED ESTIMATE

Sheet No.__ of __ Sheets__

Plan No. ______

Reference ________

Office of ____________ Date ______ 192 __

Location and description of project ____________

Account No.	Description of Unit	Unit	Quantity	Price	Total Cost	Distribution of Estimated Cost		
						Road and Equipment	Operating Expenses	
			Totals					

Estimated by ____________ Approved ____________

Checked by ____________ Approved ____________

* Fill in Individuals & Companies, Profit and Loss, Misc. Physical Property or other account titles as circumstances require.

EXHIBIT A—DETAILED ESTIMATE SHEET

Specifications—Form as shown. Size 8½x11 inches. Printed on white light bond paper; all lines and printing black.

Instructions for use—Each Request for Authority for Expenditure should be accompanied by a detailed estimate of the project on this form, unless the proposed change in the property is so small and so simple that it is deemed unnecessary to show the details of the estimate. It should be signed by the maker and approved by various officers in accordance with the prevailing organization. One copy to be attached to each copy of the A. F. E.

A complete estimate on this form should show:

1. Reference to the plan, if any—date, number and origin.
2. A brief and concise description and location of the project.
3. Estimate of cost in detail.
4. Credits, if any, for material to be recovered, etc., such as salvage from false-work, temporary tracks, and in case of a renewal on account of fire the amount of insurance recovered, and anything else that is a proper credit to the project.
5. Distribution of estimated cost as between Additions, Betterments, Renewals, Replacements, Retirements and between Other Companies and Individuals.
6. Ledger value, Estimated if not known, of property which is to be retired.

Exhibit B

NORTH & SOUTH RAILROAD

REGISTER OF AUTHORITIES FOR EXPENDITURE

	OFFICE	A.F.E.		LOCATION			DESCRIPTION OF PROJECT	DATE OF WORK		DATE OF	COSTS					
											ESTIMATED			ACTUAL		
	FILE NO.	NO.	DATE	STATE	VAL. SEC.	OPERATING DIVISION OR DISTRICT		BEGINNING	COMPLETION	COMPLETION REPORT	ROAD AND EQUIPMENT	OPERATING EXPENSES	TOTAL	ROAD AND EQUIPMENT	OPERATING EXPENSES	TOTAL

EXHIBIT B—REGISTER OF AUTHORITY FOR EXPENDITURE

Specifications—Form as here shown. Size 14x17 inches. Printed on white medium ledger paper; all lines and printing black. Horizontal lines five to the inch.

Instructions for use—As each project is authorized, the number, date, location, description and estimated cost should be entered on this form in order of the numbers assigned. As the completion reports are submitted the remaining information called for on the form should be entered at once.

This form is designed to be kept in a loose-leaf binder. One book should be kept for each owning company.

EXHIBIT C—EQUIPMENT COMPLETION REPORT

Specifications—Forms as here shown. Size 11x17 inches. All lines and printing black.

Instructions for use—A report must be prepared on this form for each equipment project by the designated officer, as soon after completion as possible, listing and describing the units of equipment affected and giving careful description of the changes made and listing the units involved, both added and retired, with the costs of each. If a project involves changes in a number of units completed in more than one six months' period a progress report should be made covering the changes completed in each six months' period. When the whole project is finished a final report shall be prepared covering all the changes made under the A. F. E., which will be a summary of all the semi-annual progress reports.

Exhibit C

North & South Railroad

Sheet No. ....of ....Sheets.

COMPLETION REPORT
OF
CHANGES MADE IN EQUIPMENT DURING THE SIX MONTHS ENDED ....19 ....
General Account 11. Equipment.

Authority	Equipment, unit numbers, names or series affected by the change.	Owner	Lessee.	Description of Equipment to which the change is applicable.	Total number of units affected.	Description of the change effected and of the other items contributing to the costs incurred.	Date of Change	COSTS INCURRED		COSTS RETIRED	
A.F.E. No.								Dr. Acct. No.	Amount	Cr. Acct. No.	Amount

I.................................... (Name) .... (Title) of the above named company do swear that the foregoing report of property changes which were made under my supervision is true to the best of my knowledge and belief.

.... (Signature)

.... (Title)

Subscribed and sworn to before me this ....day of ....19 ....

.... (Signature)

.... (Title) My Commission Expires..................................

Appendix D

(6) CONVENTIONAL SIGNS FOR ARCHITECTURAL DETAILS

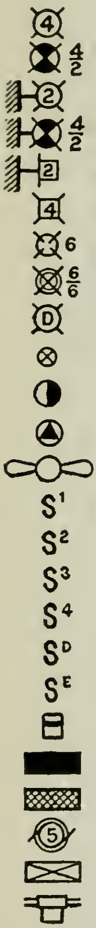
A. M. Blanchard, *Chairman;* Armstrong Chinn, Henry Lehn, W. F. Ogle, *Sub-Committee.*

The Electrical Wiring Symbols as shown, Exhibit D, have been adopted by the National Electrical Contractors' Association and the American Institute of Architects and therefore it is the opinion of your Sub-Committee that these symbols should be proposed for approval and adoption.

Below (see Exhibit E) is given a list of Architectural Symbols which have been prepared for conventional representations of architectural details. The information incorporated in the list has been gathered from all sources available and the best of the symbols have been shown.

Exhibit D

This specification is based upon the use of the following standard symbols adopted by the National Electrical Contractors' Association and the American Institute of Architects.
(Copyrighted.)



Ceiling Outlet; Electric only. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Ceiling Outlet; Combination. $\frac{4}{2}$ indicates 4-16 C. P. Standard Incandescent Lamps and 2 Gas Burners. If gas only

Bracket Outlet; Electric only. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Bracket Outlet; Combination. $\frac{4}{2}$ indicates 4-16 C. P. Standard Incandescent Lamps and 2 Gas Burners. If gas only

Wall or Baseboard Receptacle Outlet. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Floor Outlet. Numeral in center indicates number of Standard 16 C. P. Incandescent Lamps.

Outlet for Outdoor Standard or Pedestal; Electric only. Numeral indicates number of Standard 16 C. P. Incand't Lamps.

Outlet for Outdoor Standard or Pedestal; Combination. $\frac{6}{6}$ indicates 6-16 C. P. Standard Incand't Lamps; 6 Gas Burners

Drop Cord Outlet.

One Light Outlet, for Lamp Receptacle.

Arc Lamp Outlet.

Special Outlet, for Lighting, Heating and Power Current, as described in Specifications

Ceiling Fan Outlet

S^1 S. P. Switch Outlet.

S^2 D. P. Switch Outlet.

S^3 3-Way Switch Outlet.

S^4 4-Way Switch Outlet.

S^D Automatic Door Switch Outlet

S^E Electrolier Switch Outlet

Show as many Symbols as there are Switches. Or in case of a very large group of Switches, indicate number of Switches by a Roman numeral, thus S^1 XII; meaning 12 Single Pole Switches.

Describe Type of Switch in Specifications, that is, Flush or Surface, Push Button or Snap.

Meter Outlet

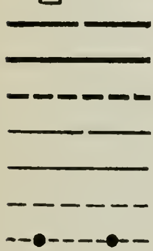
Distribution Panel.

Junction or Pull Box.

Motor Outlet; Numeral in center indicates Horse Power.

Motor Control Outlet.

Transformer



Main or Feeder run concealed under floor.

Main or Feeder run concealed under Floor above.

Main or Feeder run exposed.

Branch Circuit run concealed under Floor.

Branch Circuit run concealed under Floor above.

Branch Circuit run exposed.

Pole Line

Heights of Center of Wall Outlets (unless otherwise specified):

Living Rooms	5 ft. 6 ins.
Chambers	5 ft. 0 ins.
Offices	6 ft. 0 ins.
Corridors	6 ft. 3 ins.

Height of Switches (unless otherwise specified) 4 ft. 0 ins.

Riser

Exhibit D

This specification is based upon the use of the following standard symbols adopted by the National Electrical Contractors' Association and the American Institute of Architects.

(Copyrighted.)

Telephone Outlet; Private Service.

Telephone Outlet; Public Service.

Bell Outlet.

Buzzer Outlet.

Push Button Outlet; Numeral indicates number of Pushes.

Annunciator; Numeral indicates number of Points

Speaking Tube.

Watchman Clock Outlet.

Watchman Station Outlet.

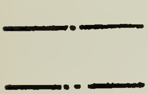
Master Time Clock Outlet.

Secondary Time Clock Outlet.

Door Opener.

Special Outlet; for Signal Systems, as described in Specifications.

Battery Outlet.

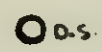
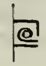
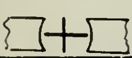
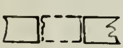
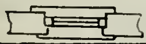
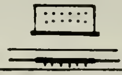
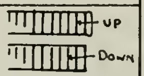
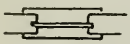


Circuit for Clock, Telephone, Bell or other Service, run under Floor, concealed.
Kind of Service wanted ascertained by Symbol to which line connects.

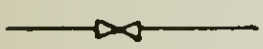
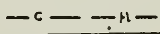
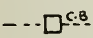
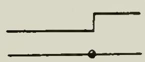
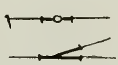
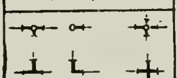
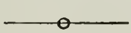
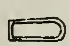
Circuit for Clock, Telephone, Bell or other Service, run under Floor above, concealed
Kind of Service wanted ascertained by Symbol to which line connects.

Exhibit E

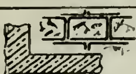
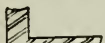
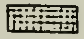
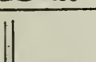
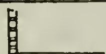
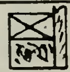
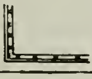
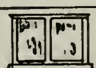
ARCHITECTURAL SYMBOLS

	Ventilators.		Pipe Railing.
	Down Spouts.		Grating.
	Down Spout Intake.		Radiator.
	Door.		Rolling Partition.
	Swing Door.		Dumb Waiter.
	Revolving Doors.		Passenger Elevator.
	Sliding Door.		Freight Elevator.
	Sliding Door.		Fireplace.
	Rolling Door.		Chimney.
	Gate.		Wall Register.
	Counter Lift.		Floor Register.
	Hung Window.		Switch Board.
	Fixed Window.		Fire Alarm Box.
	Sliding Window.		Stair.
	Lift Window.		Ladder.

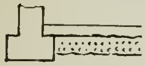
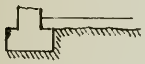
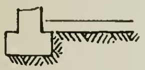
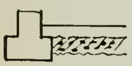
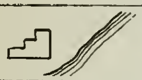
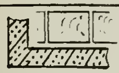
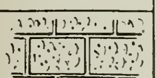
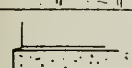
ARCHITECTURAL SYMBOLS—Continued

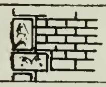
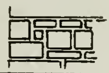
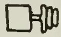
	Valve. Kind by Initials. G' = Gate, G = Globe, Ch = Check, etc.		H. P. Steam Pipe.
	Cut Out Cock.		L. P. Steam.
	Air Strainer.		Return.
	Hose Connection.		Air.
	Faucet.		Water, Hot or Cold, C or H.
	Hydrant.		Sprinkler System.
	Meter.		Gas.
	Catch Basin.		Sewer, Soil, Waste or Vent (initials).
	Coal Chute.		Riser.
	Manhole.		Wye Connection.
	Sump.		Tee, Ell, and Cross.
	Sink.		Expansion Joint.
	Closet, Low or High Tank.		Union Joint.
	Lavatory.		Trap. Kind by Initials. Bell = B, Grease = G, Tilt = T, etc.
	Bath.		Reducer.
	Drinking Fountain.		

ARCHITECTURAL SYMBOLS—Continued

	Stone.		Steel.
	Brick.		Wrought Steel.
	Concrete, Reinforced. State kind.		Cast Iron.
	Frame.		Wrought Iron.
	Random Rubble.		Malleable Iron.
	Rock Faced Ashlar.		Copper.
	Terra Cotta.		Brass.
	Hollow Tile.		Bronze.
	Brick Veneer.		Lead, Babbitt, Comp. Metal.
	Dry Stone or Rip Rap.		Corrugated Iron.
	Lath and Plaster.		Wood, Finished.
	Enameled Brick.		Wood, Rough.
	Metal Lath and Plaster.	Materials	Watered Ink.
	Enameled Tile.		Glass. State kind.
	Sheathing.		Folding Partition.

ARCHITECTURAL SYMBOLS—Continued

	Cinders.
	Earth or Clay.
	Rock.
	Gravel.
	Water Line.
	Broken Stone.
	Damp Proofing.
	Rough Cast.
	Burlap.
	Wood Panels.
	Marble.
	Terrazzo.
	Artificial Stone.
	Granite, Elevation.
	Cement, Elevation.

	Rough Cast, Elevation.
	Brick and Rock Faced Stone.
	Stone.
	Furnace.
	Boiler.
	Pump, Centrifugal, Single Stage.
	Pump, Centrifugal, Multi Stage.
	Forge.
	Anvil.
Steam, Air, and Water Pipes.	Blue Ink.
Sewers, Soil, Drainage & Vent.	Yellow.
Electric Wiring	Brown.
Alterations and Additions Old Work	Black.
New Work	Red, on B. P's, Red Wash.
Old Work To be removed	Yellow, on B. P's, Yellow Wash.

REPORT OF COMMITTEE IX—ON SIGNS, FENCES AND CROSSINGS

MARO JOHNSON, *Chairman;*
T. E. RUST, *Vice-Chairman;*
ANTON ANDERSON,
ARTHUR ANDERSON,
F. D. BATCHELLOR,
C. H. N. CONNELL,
A. CRUMPTON,
L. B. CURTIS,
A. DANIELS,
G. N. EDMONDSON,
W. J. HARRIS,
R. A. HARRY,
S. C. JUMP,
L. C. LAWTON,
O. H. SESSIONS,
S. E. SHOUP,
W. C. SWARTOUT,
R. L. TURNER,
W. D. WARREN,
K. G. WILLIAMS,

Committee.

To the American Railway Engineering Association:

Your Committee reports on the following subjects:

(1) Revision of the Manual

No changes are recommended in the Manual.

(2) Location of Roadway Signs

This subject has been given careful study, the results of which appear in Appendix A. Recommendations relating to it appear under the head of conclusions.

(3) Highway Grade Crossings

The Committee has not reached a unanimous conclusion on this subject and makes no recommendations. Tentative specifications were submitted last year and they appear in the Proceedings. Suggestions or criticism from the membership will be welcomed.

(4) Substitutes for Crossing Planks

A large amount of data has been accumulated on this subject, and is presented as information in Appendix B.

(5) Concrete Fence Posts

In Appendix C is presented tentative specifications for all concrete posts and tentative plans for round and square line posts

(6) Wood, Steel and Concrete Fence Posts

Additional data has been accumulated during the year, but the Committee is not ready to submit conclusions and does not believe advance publication of the information received would be of value,

(7) Recommendations for Future Work

The Committee recommends that the incompleted subjects, Nos. 3, 4, 5 and 6 above, be continued and suggests that in addition, consideration be given to the assignment of the following:

(1) The preparation of plans for end, corner and gate posts of concrete and for a method of bracing same.

(2) That, if possible, arrangements be made for the test of line posts constructed in accordance with tentative plans of the Committee.

(3) Make a study and report on means used for preventing the accumulation of snow and for its removal.

CONCLUSIONS

Your Committee recommends that the statement in Appendix A relating to the location of signs be adopted and printed in the Manual.

Respectfully submitted,

THE COMMITTEE ON SIGNS, FENCES AND CROSSINGS,

MARO JOHNSON, *Chairman.*

Appendix A

LOCATION OF SIGNS

G. N. Edmondson, *Chairman;* L. C. Lawton, *Vice-Chairman;* Arthur Anderson, Arthur Crumpton, W. C. Swartout, *Sub-Committee.*

In studying the location of signs, the Committee considered the safety of employees, visibility, uniformity of location, clearance and width of roadbed.

A circular was sent to a large number of railroads asking for information as to their general practice in locating signs, with the purpose of finding out if there were any unusual conditions which should be taken into consideration, also with the idea of avoiding a recommendation that would vary too much from present practice. The information obtained included the location of signs, with relation to the track; location with relation to the objects affected, and details of any local, State, or Public Service Commission laws or orders applying to the location of signs.

Summary of Replies to Questionnaire

Distances from the Track: The replies to the questionnaire show considerable variation in the distances used, but the majority are less than recommended in this report.

Distances along Track, from the object affected: In most instances, the sign itself indicates the location. Where it does not, varying locations are given in the replies.

Laws or Orders of Public Utilities Commissions: These affect primarily highway crossings, drawbridges and whistle posts. The questionnaire does not disclose any law or order which will conflict with, or vary much, from the recommendations of this report. If such variations do occur, the law, of course, will govern.

Safety and Clearance are naturally combined. This Association has previously adopted a clearance diagram applying to bridges requiring horizontal clearance of eight feet from the center of the track and signs should not encroach on this.

The Committee believes it would generally be better to adopt a uniform distance for all signs wherever possible rather than vary it for different classes of signs, the main consideration being safety for employees, which condition is controlled by distance from the track.

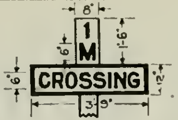
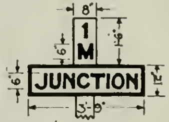
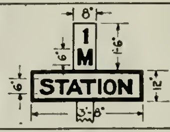
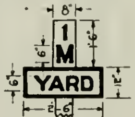
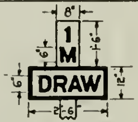
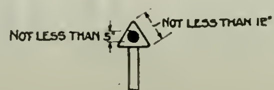
Roadbed width may also be considered important, and by roadbed width we mean the width of sub-grade. The Association has adopted a roadbed with a 10 ft. shoulder, where ordinary depths of ballast are used, and has also adopted a 11 ft. 1½ in. shoulder where sub-ballast is used.

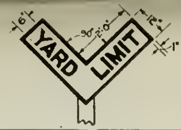
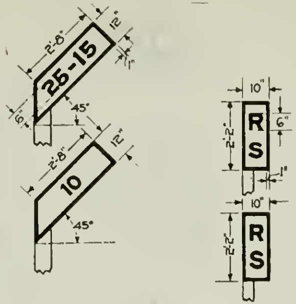
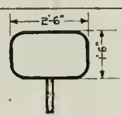
Information acquired in March and April, 1921, from 34 different railroads shows the following widths of roadbed in use:

	On Embankments	*In Cuts*
Class A Track	7′6″ to 11′6″	7′6″ to 11′6″
Class B Track	7′6″ to 10′6″	7′6″ to 10′6″
Class C Track	7′0″ to 10′0″	7′0″ to 9′0″

LOCATION OF SIGNS

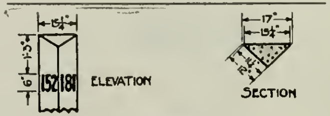
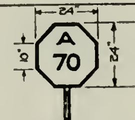
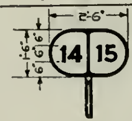
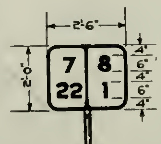
Signs Primarily for the Information of Trainmen

Name or Purpose of Sign	Sketch of Sign.	Distance at right angles from center line of track to nearest face or edge of Sign.	Distance along track from Sign to object, or condition which it describes or designates.
Railroad Crossing— Distant (one mile).................... Close (400 ft. more or less)...........		10'—4" 10'—4"	One mile. 400' more or less.
Junction—(One mile)..................		10'—4"	One mile.
Station—(One mile)...................		10'—4"	One mile.
Yard—(One mile)......................		10'—4"	One mile.
Drawbridge— Distant—(One mile)................. Close (400 ft. more or less)..........		10'—4" 10'—4"	One mile. 400' more or less.
Whistle Post— Highway............................. Station.............................		10'—4" 10'—4"	1320 ft. 1320 ft.
Flanger Sign.........................		10'—4"	60 ft.
Track Pan Posts*...................... *Between tracks vary distance out, according to track centers.		10'—4"	50 ft.

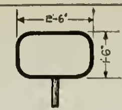
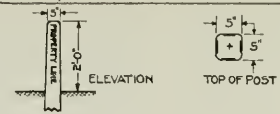
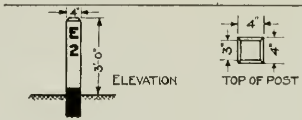
Yard Limit		10′—4″	Governed by operating condition.
Speed Limit—Permanent—Limit Slow Resume Temporary—Limit Slow Resume		10′—4″ 10′—4″ 10′—4″ 10′—4″ 10′—4″ 10′—4″	3000 ft. 50 ft. 150 ft. beyond. 3000 ft. 50 ft. 150 ft. beyond.
Water Station Limit		10′—4″	One mile.
Fuel Station Limit	"	10′—4″	One mile.
Cinder Station Limit	"	10′—4″	At Limits of Dumping.
Beginning and End of Double Track	"	10′—4″	Opposite Clearance Point.
End of Block	"	10′—4″	At Limit of Block.
Blind Siding	"	10′—4″	Opposite Switch.
Passing Siding	"	10′—4″	Opposite Switch.
Lack of Clearance	"	10′—4″	At Switch Point.

Location of Signs—Continued

Signs for the Information of Passengers and Employees Other Than Trainmen, Though Incidentally Used by Them

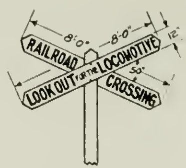
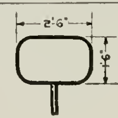
Name or Purpose of Sign.	Sketch of Sign.	Distance from center line of track to nearest face or edge of Sign where the track governs the location and side of track on which located.	Distance from other objective as station or property line to Sign where such object governs the location.
Mile Post..............................		10′—4″ ★North or east side of track or in direction leading from principal termini....	
Bridge Numbers........................		10′—4″ ★Right angles to track and side most conspicuous to passenger trains........	10′—0″
Section................................		★Parallel to track near right of way line.	
Sub-division and Section................		★Parallel to track near right of way line.	
Valuation Section......................		★Parallel to track near right of way line.	

General Remarks: ★"In accordance with information shown on plans already adopted."

Corporation or Other Political Subdivision		★Perpendicular to track near right of way line	
Property Posts			★All property corners, P. C. and P. T. of curves and 1000 ft. on tangents.
Curve and Elevation		★7'—0" from gauge of near rail	

General Remarks: ★"In accordance with information shown on plans already adopted."

Signs for the Information of or Warning to the Public

Name or Purpose of Sign	Sketch of Sign	Distance from center line of track to nearest face or edge of Sign where the track governs the location.	Distance from other objective as station or property line to Sign where such object governs the location.
Highway Crossing—At the crossing Advance warning		17'—0" 300 ft.	
Trespass—Right of way Bridge Crossing		10'—4" or as required by conditions 10'—4" Near right of way line	As required by conditions. At end of bridge. At point of trespass.

Even with the widest roadbed now in use, based on this information, it would be necessary, in order to get good clearance from the track, to build out the shoulder to properly support signs located on embankments.

Clearance required for snow plow wings, roadbed spreaders and weed destroyers which are used on practically all railroads has been investigated and we believe that sufficient clearance has been provided for this equipment.

Your Committee, therefore, has recommended the distances given on the table submitted with this report, appreciating the fact that widening of the roadbed on fills will be necessary, and further, that this is the practice in vogue on railroads at the present time where signs are located at a sufficient distance from the track to require it.

Appendix B

SUBSTITUTES FOR WOOD CROSSING PLANKS

F. D. Batchellor, *Chairman;* G. N. Edmondson, *Vice-Chairman;* Anton Anderson, C. H. N. Connell, Arthur Daniels, R. A. Harry, *Sub-Committee.*

In 1913 this Committee submitted a report on "Track Construction and Flangeways at Paved Street Crossings and in Paved Streets." That report applied more particularly to crossings constructed of the same material as the adjoining street. The present report is more general and includes all kinds of crossings. It is a preliminary report, but is presented as information at this time, because of general interest in the subject.

In recent years the high price of wood crossing plank has resulted in the introduction of a number of substitutes, of which seventeen, if paving blocks are included, have come to the attention of this Committee. These may be grouped in five classes in accordance with the material of their construction. So classified, these substitutes are listed below. The figures under the group headings indicate the number of crossings of that group included in this report.

Concrete	(a)	Solid concrete.
21	(b)	Precast slab.
	(c)	Concrete plank.
Bituminous Material	(a)	Tarvia.
57	(b)	Headley Good Roads Oil.
	(c)	Emulsified Asphalt.
	(d)	Kentucky Rock Asphalt.
	(e)	Sheet Asphalt.
	(f)	Paving Pitch.
Steel or Iron	(a)	Innus Armco Iron Highway Crossing.
3	(b)	Jennings Steel Crossing.
	(c)	Railroad Rails.
Paving Blocks	(a)	Granite.
8	(b)	Brick.
	(c)	Wood.
Ballast Material	(a)	Gravel.
1	(b)	Disintegrated Granite.

The information presented on the following pages covers 95 individual crossings, many of which were visited by members of this Committee. Data in regard to others was obtained from railroad users and from the manufacturers. For the most part, these crossings have been in use but a short time, and definite conclusions as to maintenance cost and serviceability cannot be reached. A number of roads, however, in addition to those reported on, are giving consideration to the adoption of one or the other of the substitutes. Plans or photographs of each type are included in the report.

Briefly summarized, the status of each group is as follows:

Concrete—

(a) Solid Concrete—

We do not find many crossings of this type, and, where used, they have been on tracks where there is little railroad traffic.

(b) Precast Slab—

This type of crossing has been used on a number of railroads, though of varying design. Most of the installations have been made subsequent to 1919 so that they have hardly been in service long enough to obtain information as to their durability and cost of maintenance. One thing that has been demonstrated is that when concrete slabs are placed, crossings should have good drainage to prevent heaving in winter time.

(c) Concrete Plank—

The C. B. & Q. R. R. has tried out a number of these crossings. The main trouble seems to be that the upper corners of the concrete plank disintegrate under service, indicating that such plank should have some sort of corner protection.

Bituminous Materials

There are more crossings of this type in service than any of the others. The first cost of installation is lower and they are easily installed.

Steel or Iron—Plate Type

This type of crossing is not extensively used and seems to be in an experimental stage. One of these was installed in 1918, on the C. C. C. & St. L. Ry., at 71st Street, Carthage, Ohio. After seventeen or eighteen months it was taken up on account of the plates not being heavy enough to carry the trucks which passed over them. These crossings are now being made of heavier material. One will be installed on the B. & O. R. R. at Cincinnati, Ohio. There seems to be a tendency for horsedrawn vehicles to avoid this type of crossing when possible.

Railroad Rails—Steel or Iron

These crossings consist of rails laid between the running rails, and spaces filled in with concrete or other material. They have not been used in high speed tracks.

Paving Blocks

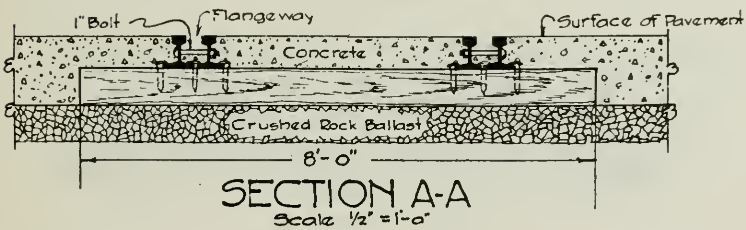
This type of crossing is used mostly in cities and particularly where the adjacent street is paved with blocks or where ordinances require their use.

Ballast Material

Crossings of this type seem to be used mostly at farm crossings, and on highways with light traffic.

Monolithic Concrete Crossing

M., St. P. & S. S. M. Ry., Waukesha, Wis.



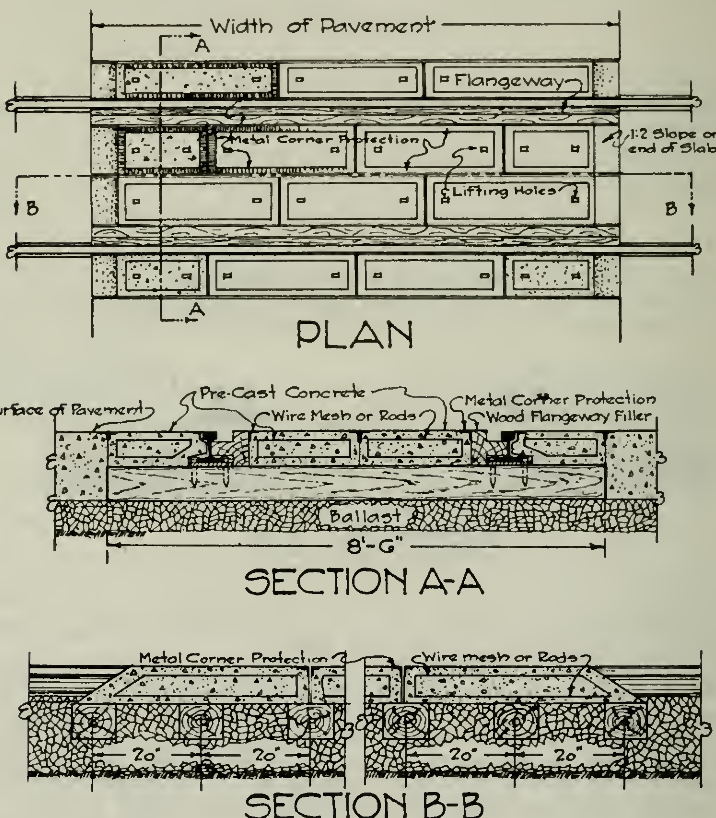
Crossing installed, 1915. Cost per sq. ft. 15 cents. Average number vehicles using crossing per 24 hours, 2,500.

Description—Old ballast was removed and replaced with crushed rock and new oak ties put in. The Railroad Company put track in shape and fastened guard rails. Concrete was placed by Contractor, who paved street. Concrete extends from bottom of ties to top of rails and between main rail and guard rail, up to the top of the 1-inch bolt tying them together. Contract price for paving was 15 cents per sq. ft. This does not include any work done in preparing the roadbed or track.

This crossing has been in service about 6 years. There has been no maintenance connected with it, except for the cracks, the total cost being about $5.00.

Concrete Slab Crossing

C., M. & St. P. Ry., Cedar Rapids, Iowa.



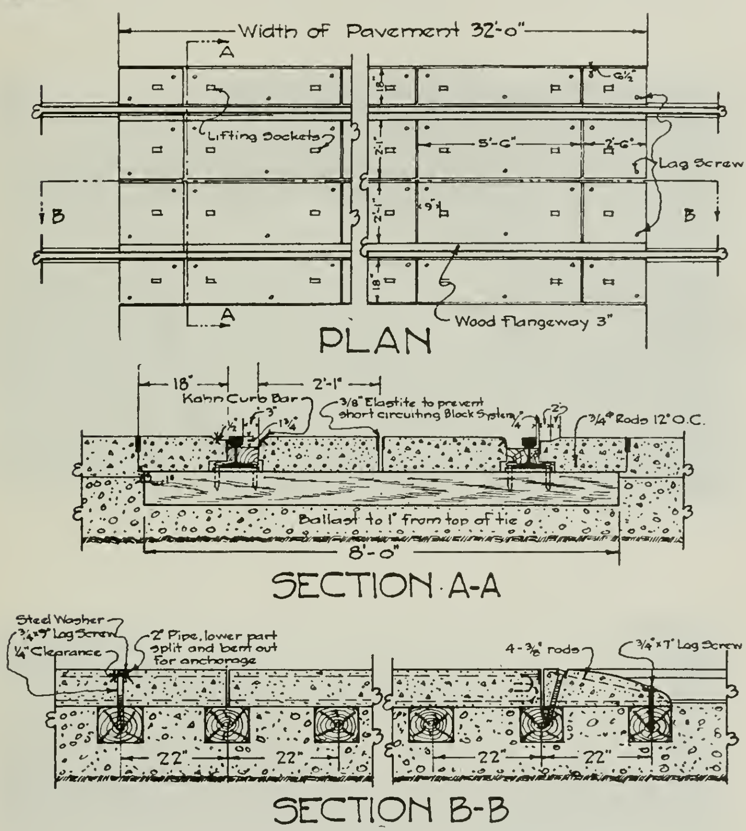
Crossing installed, March, 1918. Cost per sq. ft., 57 cents.

Description—Concrete slabs were installed on two tracks of the C., M. & St. P. Ry., one track C. R. I. & P. Ry., and two tracks of the C. & N. W. Ry. The street is paved with asphalt with the exception of the Crossings. The five tracks are paved with Concrete slabs between the rails and for a distance of 1 ft., 6 in. outside the rails. The tracks were not well ballasted before the installation and provision was not made for drainage. The cost of 57 cents per sq. ft. is only the cost of manufacturing the slabs and does not include placing them.

The only maintenance expense incurred has been in removing the slabs to resurface the tracks. However, in the five tracks there are thirteen slabs that need renewal. Considering the traffic, these slabs are holding up fairly well, but have been more or less damaged by being picked up and replaced to permit resurfacing of the track.

Concrete Slab Crossing

Illinois Central—Chester Ave., Champaign, Ill.



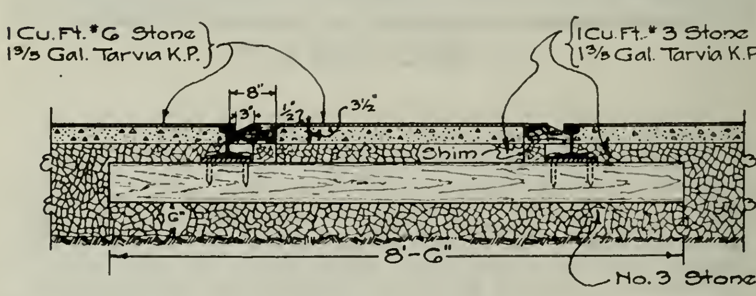
Crossing installed, May, 1920. Cost per sq. ft., $1.60. Average number vehicles using crossing per 24 hours, 1,600.

Description—The slabs are pre-cast and placed directly on the ties. To prevent creeping they are fastened to the ties with ¾-in. x 9-in. leg screws. The edges are protected by ¼-in. metal strips and where the wear is unusually great, Kahn Curb bars are provided. Beveled ramps are cast on the ends of the slabs, inside and outside of the rails, to prevent dragging parts on moving trains tearing up the crossing. The inside slabs are 5 ft., 6 in. long and 25 in. wide, while the outside slabs are 18 in. wide and the same length. Reinforcing rods used as shown in plan. The cost of this crossing was $1.60 per sq. ft. in place.

This crossing was installed May 26, 1920, and as yet shows no wear. There has been no maintenance expense and the crossing has proven entirely satisfactory.

Tarvia K. P. Crossing

B. & O.—Third Street, Dayton, Ohio



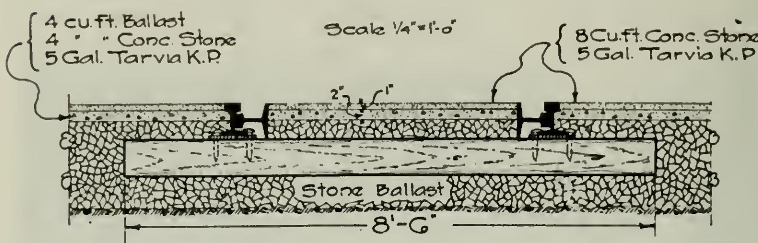
Crossing Installed, October, 1921. Cost per sq. ft., 22 cents. Average number vehicles using crossing per 24 hours, 1,000.

DESCRIPTION—Tracks were first put in good condition, ties renewed and fully tie-plated, ballast thoroughly cleaned to a depth of 6 in. below the bottom of the tie over the full width of the Crossing, tracks were lined and surfaced, rail renewed, if necessary, and good drainage provided. An 8-in. plank, 4 in. thick, beveled to provide the proper flangeways, was then placed on the inside of each rail and at the ends of the crossing, level with the top of the rail. While the above work was being done, two mixtures of clean stone and Tarvia K. P. were made. One consisted of ¾-in. to 1¾-in. stone, and one of the particles of stone up to ½ in. in size, mixed in the proportions of 1 3/5 cu. ft. of stone to 1 gal. of Tarvia K. P. and allowed to cure for a period of 24 to 48 hours before using. After the mixtures were thoroughly cured, the coarser one was spread over the railway 3½ in. deep, and after being thoroughly tamped, a sufficient quantity of the finer mixture was spread over this to make it level with the top of the rail, after being thoroughly tamped and rolled. The City of Dayton furnished a roller to roll the Crossing, at cost.

Crossings of this kind which have been in service for two years have required only a slight amount of maintenance, which can be done at a cost of approximately 3 cents per sq. ft.; others which have been in service on densely traveled streets required no maintenance after a period of one year. The City of Dayton at first objected to the installation of these crossings in 1918, but after allowing the construction of one crossing, are now insisting that all crossings be made of the same construction.

Tarvia Crossing

B. & O. C. T.—121st Street, Whiting, Ind.



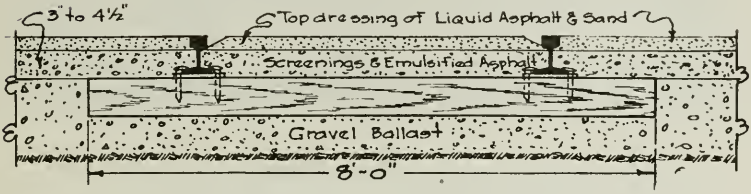
Crossing installed, May, 1920. Cost per sq. ft., 33 cents.

Description—Good drainage was first furnished crossing and track put in good condition with regard to ties and ballast. Stone Ballast was placed to within 3 in. of the top of the rail. On top of this a mixture of 4 cu. ft. of ballast and 4 cu. ft. of concrete stone and 5 gals. of Tarvia K. P. was placed; on top of this a top dressing of 8 cu. ft. of concrete stone and 5 gals. Tarvia K. P. was used. The mixture was not rolled as there were sufficient heavy trucks going over this crossing to act as a roller. On one installation stone screenings were tried, but it was found that they absorbed too much of the Tarvia, and therefore were not used in the crossing in question.

This crossing has been in service about a year and is giving good service. The town people seem well satisfied with it.

Emulsified Asphalt Crossing

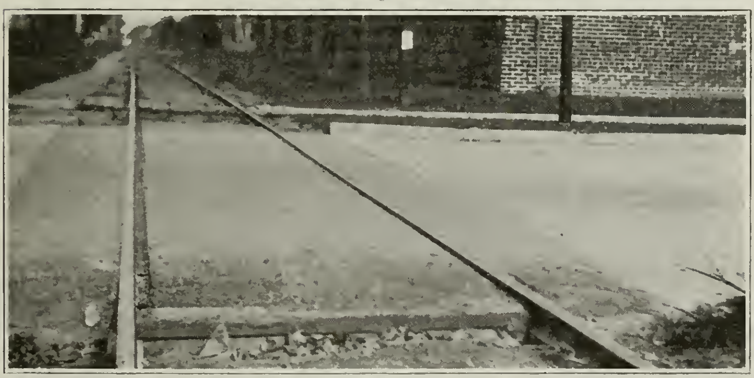
CEN. IND. R. R.—BROWN ST., ANDERSON, IND.



Crossing installed, November, 1920. Cost per sq. ft., 24 cents. Average number vehicles using crossing per 24 hours, 500.

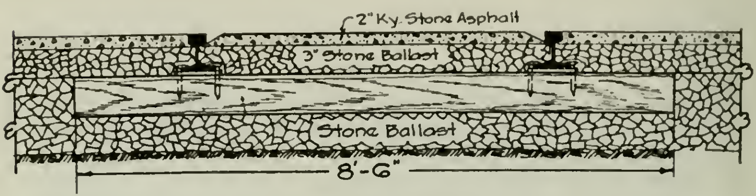
DESCRIPTION—All ties and angle bars were renewed and rails tie plated. Crossing was then filled to top of rails with new gravel and allowed to pack for about two weeks. Surface was then removed to a depth of 3 in. to 4½ in. and emulsified asphalt, ready mixed, with screenings, applied, rolled or tamped firmly. Top dressing of liquid asphalt and sand then applied. No flange rail was used.

This crossing, installed November 12, 1920, is in excellent condition, and has proven satisfactory in every respect. Used by about 500 vehicles every 24 hours.



Kentucky Rock Asphalt Crossing

C. & O. Ry.—Augusta, Ky.



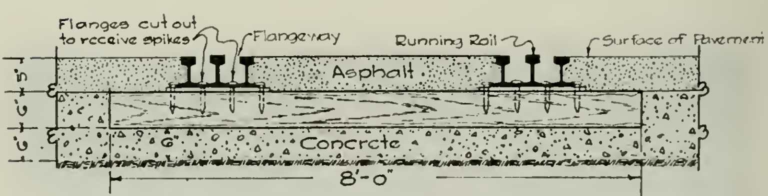
Crossing installed, October, 1920. Cost per sq. ft., 26 cents. Average number of vehicles using crossing per 24 hours, 998.

Description—Good drainage was first furnished crossing and track pulled and put in good condition as to ties and ballast. Stone ballast was then placed to within 2 in. of the top of the rail. On top of this was placed a mixture of Kentucky Rock Asphalt to a thickness of 2 in. The mixture was then rolled with a steam road roller and the crossing put in service.

This crossing has been in service one year and is giving excellent service. The town people are well satisfied with it, as many other crossings of the same material.

Asphalt Crossing

C. & E. I. R. R.—First Ave., Evansville, Ind.



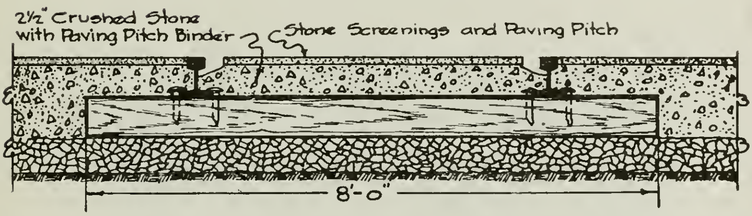
Crossing installed, 1921. Cost per sq. ft., 75 cents. Average number vehicles using crossing per 24 hours, 1,000.

Description—The crossing was installed in 1921. New ties were put in and rails tie plated. A concrete base was installed to a depth of 6 in. below bottom of ties. Rails were placed on each side of running rail and at ends to form flangeways and headers. These rails were notched out to fit close up to the running rail. A 5-in. standard asphalt street surface was then put on. Estimated cost was 75 cent per sq. ft. On account of cutting out flange rails for spikes by hand, the cost was much larger than it would have been if notches had been burned in with acetylene torch.

This crossing is in excellent condition. Has been in service for about six months and shows no sign of wear under heavy traffic.

Paving Pitch Crossing

T. H., I. & E. R. R., Terre Haute, Ind.



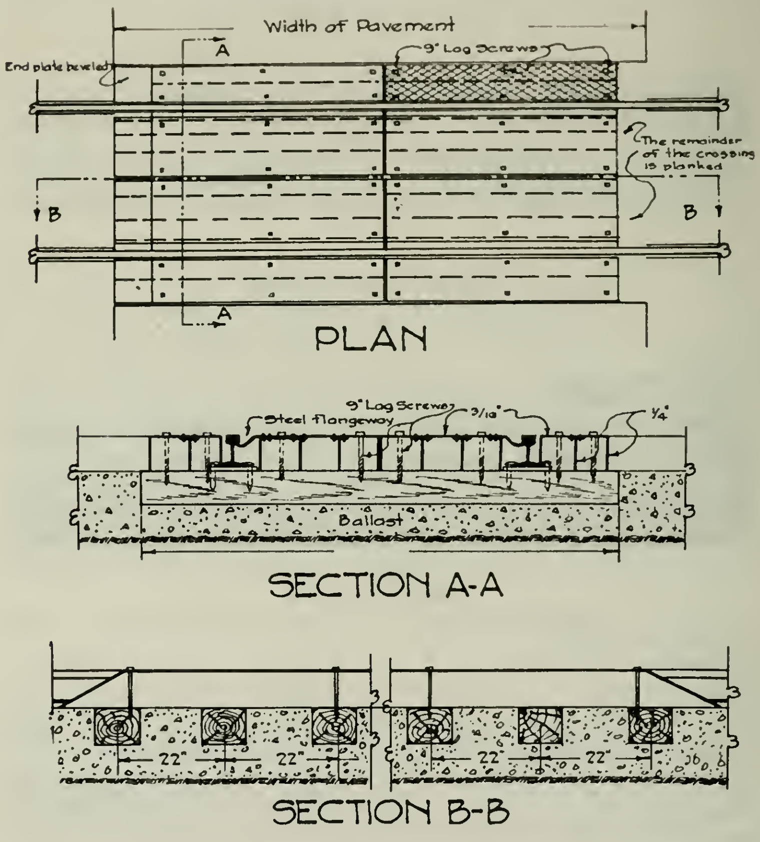
Crossing installed, 1919. Average number of vehicles using crossing per 24 hours, 1,200.

Description—This crossing was installed in 1919. Ballast was removed to bottom of ties and then large size crushed stone put in and hot paving pitch poured on. Next a dressing of screenings and another coat of paving pitch. Thoroughly tamped in place. Standard Asphalt Refining Company's paving pitch used. No cost data available.

Crossing was damaged in 1920 by an interurban car leaving track and was patched with Tarvia. Also patched by Indiana State Highway Commission with emulsified asphalt. Apparently giving good service under heavy traffic.

Steel Crossing—Plate Type

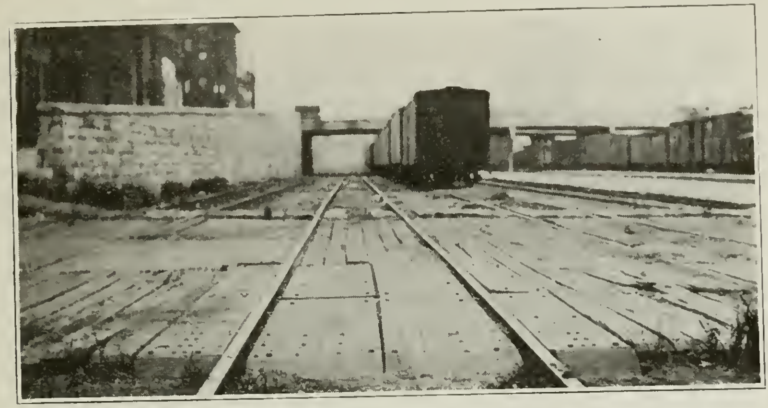
C. & N. W. Ry., Chicago, Ill.



Crossing installed, February, 1921. Average number of vehicles using crossing per 24 hours, 900.

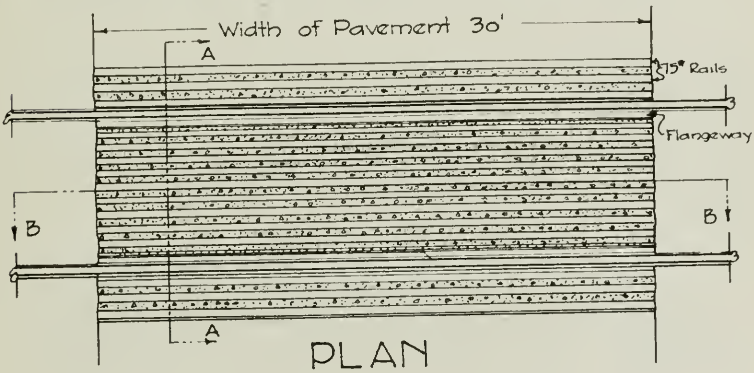
Description—Crossing was installed by the manufacturers at their own expense. The ties were about 9 months old when the crossing was put in. It is fastened to the ties by 9 in. lag screws. No work was done on the track in preparation for the installation.

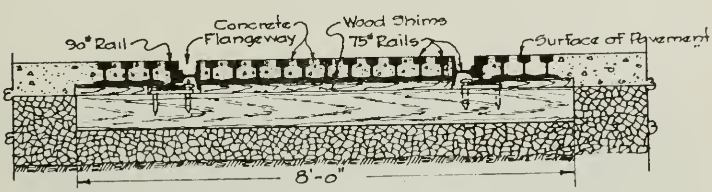
Present crossing has been in service about six or seven months. The lag screws are loose and the sections of the crossing work up and down under the heavy traffic. On account of being located on one side of the center of the street, it does not receive a fair trial. The rest of the crossing is planked. Horse drawn vehicles seem to avoid the steel, if possible. The loads passing over are heavy, and the top of the steel crossing is slightly bent. This might be overcome by placing a steel plate on top of the tie.



Steel Crossing—Railroad Rails

C. I. & L. R. R.—Lafayette, Ind.





Crossing installed, 1915. Cost per sq. ft., 50 cents. Average number of vehicles using crossing per 24 hours, 300.

Description—Crossing installed in 1915. Ties and rails being renewed and light rail bases laid touching between the running rails and spaces filled with concrete. The first rail on each side being laid with the ball next to the running rail so as to form a flangeway.

There has been no maintenance to date and the crossing is in excellent condition. About 300 vehicles use it every twenty four hours. The cost of the crossing depends upon the scrap price of the rail. The laboi for installing is not much greater than that of 4-in. plank crossings.

Concrete Crossings

RAILROAD	LOCATION	KIND OF CROSSING	Cost Per Square Foot	Date Installed	REMARKS
M. St. P. & S. S. M.	Waukesha, Wis.	Solid Concrete	$0.15	1915	Crossing in good condition, 1921; few cracks filled in with tar.
Southern	Buechel, Ky.	Concrete Slab	.56	......	Cracked and spalled, but has given fair service.
M. St. P. & S. S. M.	Fond du Lac, Wis.	Concrete Slab	1.10	1917	Crossing on spur track in poor condition, due to slabs breaking, account poor concrete.
C. M. & St. P.	Cedar Rapids, Iowa	Concrete Slab	.57	1918	Crossing not in good condition, due to slabs having to be picked up to re-surface track account poor drainage; 13 of the 280 slabs need renewing.
F. W. & R. G.	Fort Worth, Tex. (Landrum St.)	Concrete Slab	2.65	1921	Crossing in good condition.
F. W. & R. G.	Fort Worth, Tex. (Ballinger St.)	Concrete Slab	1.99	1921	Crossing in good condition.
F. W. & R. G.	Fort Worth, Tex. (Daggett St.)	Concret Slab	1.64	1921	Crossing in good condition.
I. C.	Champaign, Ill. (Chester St.)	Concrete Slab	1.60	5-26-1920	In excellent condition and standing up well under heavy traffic.
C. C. C. & St. L.	Urbana, Ill.	Concrete Slab	.86	April, 1921	Crossing in excellent condition.
C. C. C. & St. L.	Indianapolis, Ind. (Speedway Crossing)	Concrete Slab	.86	April, 1921	Fair condition; some block chipping and cracking.
C. C. C. & St. L.	Indianapolis, Ind. (Washington St.)	Concrete Slab	.86	April, 1921	Bad condition, concrete breaking away from reinforcing. Not giving good service.
Erie	Paterson, N. J.	Concrete Slab	......	January, 1912	Slabs removed when they failed.
Mich. Cent.	Wayne, Mich. (Munroe Ave.)	Concrete Slab	......	1919	......
Mich. Central	Jackson, Mich.	Concrete Slab	......	......	......
A. T. & S. F.	Bandine, Cal. (Norwalk St.)	Concrete Slab	......	1921	......
Frisco	Forth Worth, Tex.	Concrete Slab	......	1921	......
Penna.	New Brunswick, N. J. (Lincoln Highway)	Concrete Slab	......	1920	......
Long Island	Hicksville, L. I.	Concrete Slab	......	1921	......
C. B. & Q.	Downers Grove, Ill. (Main St.)	Concrete Plank	.31	May, 1917	Corners of Plank disintegrated.
C. B. & Q.	La Grange, Ill. (Brianard Ave.)	Concrete Plank	.43½	1917	......
C. B. & Q.	La Grange, Ill. (Ashland Ave.)	Concrete Plank	.42	1918	......
C. B. & Q.	La Grange, Ill. (Fifth Ave.)	Concrete Plank	.40	1918	......

Bituminous Crossings

N. & W.	Portlock, Va.	Tarvia "B"	$0.10	1920	
N. & W.	Yadkin, Va.	Tarvia "B"	.06	1920	
N. & W	Hollins, Va.	Tarvia "B"	.11	1920	
N. & W.	New Bohemia, Va.	Tarvia "KP"	.21	1920	
N. & W.	Salem, Va.	Tarvia, "KP"	.16	1920	
B. & O.	Hamilton, O. (5th St.)	Tarvia "KP"	.20	July, 1921	Good condition, giving satisfaction.
B. & O.	West Middletown, O.	Tarvia "KP"	.19	July, 1918	Fair condition, will require about $10.00 maintenance.
B. & O.	Dayton, O. (Jefferson St.)	Tarvia "KP"	.19	July, 1921	Good condition.
B. & O.	Dayton, O. (Ludlow St.)	Tarvia "KP"	.21	May, 1921	Good condition.
B. & O.	Dayton, O. (Main St.)	Tarvia "KP"	.20	May, 1921	Tarvia in street car crossing frogs only.
B. & O.	Dayton, O. (Wyandott St.)	Tarvia "KP"	.22	June, 1920	60' crossing will require $40.00 maintenance.
B. & O.	Dayton, O. Third St.	Tarvia "KP"	.22	Oct., 1921	Good condition.
B. & O.	Dayton, O. (First St.)	Tarvia "KP"	.22	Sept., 1921	Good condition.
B. & O.	Dayton, O. (Front St.)	Tarvia "KP"	.21	Sept., 1921	Good condition.
B. & O.	Dayton, O. (First St.)	Tarvia "KP"	.19	Sept., 1921	Crossing on branch line, in good condition.
B. & O.	Dayton, O. (Second St.)	Tarvia "KP"	.19	Aug., 1920	Fair condition, will require .02c per sq. ft. maintenance.
B. & O. C. T.	Whiting, Ind.	Tarvia "KP"	.33	May, 1920	Crossing in good condition. Located on main line.
B. & O.	Dayton, O. (Monument Ave.)	Tarvia "KP"	.22	June, 1920	Crossing in good condition.
B. & O.	Sidney, O.	Tarvia "KP"	.20	Aug., 1919	Crossing in fair condition, will require $0.3 sq. ft. maintenance.
B. & O.	Lima, O. (Main St.)	Tarvia "KP"	.22	Sept., 1921	Crossing in good condition.
B. & O.	Wapakonetta, O.	Tarvia "KP"	....	Sept., 1921	5 crossings now under construction.
B. & O.	Wapakonetta, O.	Tarvia "B"	....	July, 1921	2 crossings, giving good service.
C. & E. I.	Evansville, Ind. (John St.)	Tarvia	.17	1916	Repaired in 1921 at a cost of $0.02¼ per sq. ft. now in good condition.
C. & E. I.	Evansville, Ind. (Main St.)	Tarvia	.17	1920	Condition fair, broken at rail joints and showing wear under heavy traffic.
B. & O. S. W.	Vincennes, Ind.	Tarvia	....	....	Condition good, except plank headers need renewing.
Erie	Warren, O.	Tarvia	....	....	Good condition.

BITUMINOUS CROSSINGS—Continued

RAILROAD	LOCATION	KIND OF CROSSING	Cost Per Square Foot	Date Installed	REMARKS
N. Y. N. H. & H	Various	Headly Oil #1	....	....	Used these crossings since 1920. Giving good service.
D. L. & W.	Various	Headly Oil #1	....	....	Used these crossings since 1920. Giving good service.
N. & W.	Roanoke, Va (Holiday St.)	Headly Oil #1	$0.21	June, 1920	....
N. & W.	Pulaski	Headly Oil #1	.18	Sept., 1921	Three crossings installed.
N. & W.	Cincinnati, O	Headly Oil #1	....	1921	One crossing; at Montgomery.
B. & A.	Huntington, Mass (Russell St.)	Headly Oil #1	.24	Nov., 1920	Crossing satisfactory.
B. & A.	Huntington, Mass (Main St.)	Headly Oil #1	.25	Nov., 1920	Crossing satisfactory.
L. V.	Various	Headly Oil #1	....	....	Crossings very satisfactory.
B. & O.	McKeesport, Pa	Headly Oil #1	....	1920	In good condition.
L. E. & W.	Indianapolis, Ind (38th St.)	Emulsified Asphalt	.55	June, 1920	Good condition.
L. E. & W.	Indianapolis, Ind (22nd St.)	Emulsified Asphalt	55	June, 1920	Good condition.
L. E. & W.	Muncie, Ind Wyser St.	Emulsified Asphalt	.55	June, 1920	Fair condition, broken at joints and along outside rail.
L. E. & W.	Muacie, Ind Grandville Road.	Emulsified Asphalt	.55	Nov., 1920	Good condition except broken at rail joints.
L. E. & W.	Muncie, Ind Willard St.	Emulsified Asphalt	.55	Oct., 1920	Good condition, wearing slightly where wheels leave rails.
L. E. & W.	Muncie, Ind Liberty St.	Emulsified Asphalt	.55	Oct., 1920	Fair condition except at rail joints.
L. E. & W.	Muncie, Ind West Victor St.	Emulsified Asphalt	.55	Nov., 1920	Condition good, giving excellent service.
Central Ind.	Anderson, Ind Nichol Ave.	Emulsified Asphalt	.24	Nov., 1920	Very good condition.
Central Ind.	Anderson, Ind Eighth St.	Emulsified Asphalt	.24	Nov., 1920	Condition excellent, giving good service under heavy traffic.
Central Ind.	Anderson, Ind Madison Ave.	Emulsified Asphalt	.24	Nov., 1920	Good condition.
Central Ind.	Anderson, Ind Brown St.	Emulsified Asphalt	.24	Nov., 1920	Excellent condition.
Central Ind.	Anderson, Ind Fletcher St.	Emulsified Asphalt	.26	April, 1921	Good condition, showing some wear under heavy traffic.

BITUMINOUS CROSSINGS—Continued

Central Ind.	Anderson, Ind. Huffman Road.	Emulsified Asphalt	$0.26	June, 1921	In excellent condition.
C. & O.	Augusta, Ky. Upper Ave.	Kentucky Natural Asphalt	.26	Nov., 1920	Good condition.
C. & O.	Augusta, Ky. Seminary Ave.	Kentucky Natural Asphalt.	.26	Oct., 1920	Good condition.
C. & E. I.	Evansville, Ind. First Ave.	Sheet Asphalt	.75	1921	Condition excellent, giving good service.
C. & E. I.	Evansville, Ind. Franklin St.	Sheet Asphalt	.70	1920	Good condition except plank headers are warped and need renewing.
T. H. I. & E.	Terre Haute, Ind.	Paving Pitch	....	1919	In good condition and giving good service under heavy traffic. Was damaged by traction car and repaired with tarvia and emulsified asphalt.

STEEL CROSSINGS

C. & N. W.	Chicago, Ill.	Jennings	....	Feb., 1921	Lag screws loose, sections of crossing work up and under traffic. On account of being located on one side of street, does not receive fair trial. Top of steel slightly bent.
C. B. & Q.	Burlington, Iowa	....	....	....	....
D. T. & I.	Detroit, Mich.	....	....	....	....

PAVING BLOCK

Erie	Passaic, N. J.	Wood Block	$0.52	1917	Good condition. Blocks sawed from old bridge timbers.
Erie	Stroudsburg, Pa.	....	....	1917	Good condition.
F. W. & R. G.	Fort Worth, Tex. Hemphill St.	Brick	1.96	March, 1921	Good condition.
St. L. S. F. & T.	Fort Worth, Tex. North Main St.	Brick	1.33	Feb., 1921	Concrete base, good condition.
Southern	Evansville, Ind. Heidelbach Ave.	Brick	....	1916	Sand cushion, excellent condition.
C. N. O. & T. P.	Lexington, Ky.	Brick	....	1912	Sand cushion, good condition.
M. C.	Toledo, Ohio. Dorr St.	Wood Block, "Kreolite"	....	1916	....
Penna.	Toledo, Ohio. E. Main St.	....	....	....	....

Steel Crossings—Railroad Rails

RAILROAD	LOCATION	KIND OF CROSSING	Cost Per Square Foot	Date Installed	REMARKS
Penna.	Louisville, Ky.	Rail	$0.75	....	Six crossings in excellent condition, requiring no attention except when ties are renewed.
Southern	Louisville, Ky.	Rail	.52	....	Condition excellent.
C. I. & L.	New Albany, Ind.	Rail	.82	1914	Condition good, no repairs since installation.
C. I. & L.	La Fayette, Ind.	Rail	.50	1915	Condition excellent, shows no wear.
C. I. & L.	La Fayette, Ind.	Rail	.92	1921	5th and Ferry St.

GRAVEL CROSSINGS

RAILROAD	LOCATION	KIND OF CROSSING	Cost Per Square Foot	Date Installed	REMARKS
U. P.	Various	Disintegrated Granite	....	....	....

Appendix C

PLANS AND SPECIFICATIONS FOR CONCRETE FENCE POSTS

T. E. Rust, *Chairman;* O. H. Sessions,
Arthur Anderson, *Vice-Chairman;* W. C. Swartout,
L. B. Curtis, *Sub-Committee.*

The Sub-Committee to which was assigned the preparation of plans and specifications for concrete fence posts has prepared and submits herewith plans of round and square concrete line posts and specifications sufficiently general to cover concrete fence posts of any size. The Sub-Committee recommends that these plans and specifications be submitted to the Association for information and criticism. Plans for concrete end and corner posts have not yet been prepared.

Specifications.—The specifications herewith submitted follow, in general, the Tentative Specifications for Concrete and Reinforced Concrete of the Joint Committee of this Association, the American Society of Civil Engineers, the American Society for Testing Materials, the American Concrete Institute and the Portland Cement Association, which specifications were submitted to the constituent organizations on June 4, 1921. A great deal of matter not considered applicable to concrete fence posts has been omitted and other things have been added, but the spirit of these Tentative Specifications has been followed quite closely. The reason for following these Tentative Specifications rather than the specifications heretofore adopted by this Association is that the former presumably reflect the latest developments in the art of making concrete. We also considered that it was probable that this Association would, as soon as the Joint Committee submits its final report, adopt specifications very closely following such tentative specifications. The Sub-Committee does not believe that this Association should adopt any specifications for concrete posts at this time and perhaps not until revised specifications for concrete and reinforced concrete have been adopted. The accompanying specifications are submitted for information and for criticism as to their scope, arrangement and special features, so that the Association will have, when such revised specifications for concrete are adopted, a set of specifications for concrete fence posts which will require only minor revision.

Plans.—The plans and specifications for concrete fence posts must be considered as a unit. The plans herewith submitted were drawn with the assumption that the materials used and methods employed would be in accordance with the specifications. For this reason the Sub-Committee asks that the plans be not adopted separately, as they are, like the specifications, submitted for information and criticism.

Some information regarding the posts shown on the plans is given in the following table:

	Square Post	Round Post
Average sectional area of post 7 ft. long	13,915 sq. in.	14,333 sq. in.
Sectional area of steel, wire reinforcing	.0984 sq. in.	.1232 sq. in.
Sectional area of steel, bar reinforcing	.1104 sq. in.	.1656 sq. in.
Volume of post 7 ft. long	.676 cu. ft.	.697 cu. ft.
Approximate weight of post 7 ft. long	101 lb.	104 lb.
Weight of steel, wire reinforcing	2.34 lb.	2.94 lb.
Weight of steel, bar reinforcing	2.63 lb.	3.94 lb.
Approximate ultimate strength of post, wire reinforcing	219 lb.	192 lb.
Approximate ultimate strength of post, bar reinforcing	219 lb.	224 lb.

The "ultimate strength" shown above is the load which, applied at the small end of the post would cause the post to fail as a cantilever beam, the point of support being 60" from the load. The breaking load is calculated by the ordinary formulae for beams reinforced top and bottom, the ultimate strength of cold drawn steel wire being assumed to be 90,000 lb. per sq. in., and of hard steel bars 80,000 lb. per sq. in. In 1917 the Association adopted the conclusion that, "it is not economical to make posts that will have the strength to resist a force of over 200 lb. when the post is tested in the manner above described." The use of the next smallest commercial size of reinforcing in the posts shown on the plans would reduce the force which the posts could resist to considerably less than 200 lb. and is not advocated. As to the reasonableness of the ultimate strengths of steel referred to above it may be stated that the average ultimate strength of the wire reinforcing in posts tested by Committee IX in 1914 was about 100,000 lb. per sq. in. At that time three round posts ½" larger in diameter than the post shown on the plans and reinforced with six No. 8 wires were tested and the average strength found to be considerably in excess of that given above, allowance being made for the difference in size.

In deciding on the size of posts and amount of reinforcing, as shown on the accompanying plans, the Sub-committee was guided by the conclusions already adopted by the Association, the tests made in 1914, theoretical calculations made this year as to the strength of posts of various sizes, and, more particularly, the record of posts now in service. There are nearly a half million round posts in use by railroads, of the size shown on the Committee's plans and reinforced with six No. 8 or No. 9 wires, which are giving satisfaction and the Committee could not justify the use of a larger section or heavier reinforcing. The size and reinforcing decided upon for square posts is such as to give them a strength substantially the same as that of the round posts. The Committee suggests that it might be well, during the coming season, to test posts made in accordance with the plans and specifications herewith submitted and using rods and wires whose ultimate strength and elastic limit have been previously tested. Possibly such tests might result in more definite specifications as to proportions of ingredients and amount of water used in mixing as well as confirming the theoretical calculations as to strength.

The Committee repeats its former conclusions as to the relative merits of round and square posts. Viewed as a beam the square section seems obviously superior. The above table shows a saving in both concrete and steel by the use of square posts. On the other hand the round post is perhaps superior in resisting fire and disintegration. The methods used in the manufacture of round posts have probably been better than those usually employed in the manufacture of square posts, but the Committee can see no reason why the same methods could not just as well be employed in both cases. The Committee also believes that "U" shaped posts, if properly made and reinforced, will be entirely satisfactory. This type of post has lost favor with railroads more because of improper reinforcing than on account of any defect in the shape of the post, which differs very little from that of a square post. Most of these posts have been reinforced with flat bars, a shape which seems to cause longitudinal cracks in the concrete and which, also, does not give as good adhesion as a round or square bar.

The Sub-Committee is not yet prepared to submit plans for corner, end or gate posts, or methods of bracing end and corner panels. A few examples of such posts and methods of bracing are submitted for information. No two roads, apparently, use the same size of end posts or the same style of bracing.

RECOMMENDED SPECIFICATIONS FOR CONCRETE FENCE POSTS

(1) Materials

1. **Intent.** The intent of these specifications and the plans of which they form a part is to produce concrete fence posts having a uniform and sufficient strength and durability at a minimum of cost. On account of the thinness of the section, this can only be accomplished by intelligent and constant attention to securing proper proportions of all ingredients.

2. **Cement.** Cement shall conform to the present Standard Specifications and Tests for Portland Cement of the American Railway Engineering Association and subsequent revisions thereof.

3. **Fine Aggregate.** Fine aggregate shall consist of sand, stone screenings, or a combination thereof, having clean, hard, strong, durable, uncoated grains, and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances. It shall range in size from fine to coarse, preferably within the following limits:

Passing through a No. 4 sieve	not less than 95%
Passing through a No. 50 sieve	not more than 30%
Weight removed by decantation	not more than 3%

4. **Coarse Aggregate.** Coarse aggregate shall consist of crushed stone, gravel, or combination thereof, having clean, hard, strong, durable, uncoated particles free from injurious amounts of soft, friable, thin, elongated or laminated pieces, organic or other deleterious matter. It shall range in size from fine to coarse within the following limits:

Passing a ½" screen	not less than 95%
Passing a No. 4 screen	not more than 15%
Passing a No. 8 screen	not more than 5%

5. **Bank Gravel.** Natural combinations of fine and coarse aggregate, in the form of bank gravel, may be used providing its particles meet all the requirements in paragraphs 2 and 3 above, and provided such particles are properly graded from fine to coarse within the following limits:

Passing a ½" screen	not less than 95%
Passing a ¼" screen	from 35% to 55%
Passing a No. 50 screen	not more than 15%
Weight removed by decantation	not more than 1½%

6. **Water.** Water for concrete shall be clean and free from oil, acid, alkali, organic or other deleterious substance.

7. **Metal Reinforcement.** Steel reinforcement shall be hard steel and shall conform to the present Standard Specifications for Steel Reinforcement of the American Railway Engineering Association or, if wire is used, to the present Tentative Specifications for Cold-Drawn Steel Wire of the American Society for Testing Materials, or to such modifications of either of such specifications as may hereafter be adopted by the American Railway Engineering Association. Reinforcement shall be in the form of round or square bars, preferably deformed, or steel wires. Crimped, stranded or flat reinforcing shall not be used. Reinforcing, before being placed in the molds, shall be thoroughly cleaned of mill and rust scale, and of coating that will destroy or reduce the bond.

(II) Proportioning and Mixing Concrete

8. **Proportioning.** The unit of measure shall be the cubic foot, One bag of Portland cement shall be considered as one cubic foot. Each of the constituent materials shall be measured separately by volume, using a method which will secure the specified proportions. The water shall be measured by an automatic device that will secure the same quantity in successive batches.

9. **Strength.** The proportions of cement, water and aggregate shall be such as to produce a concrete having a compressive strength at 28 days of 2,000 lb. per sq. in. The proportions of fine and coarse aggregate to produce such a concrete shall be determined by making a screen analysis of the available aggregates and using such a mixture as will secure a maximum density. To such a mixture sufficient cement shall then be added to produce concrete of the desired strength. If bank gravel is used it shall be screened and remixed, if necessary in order to produce

concrete of the desired strength, or if such screening and remixing will produce concrete of the desired strength with enough less cement so that the saving in the cost of cement will exceed the cost of screening and remixing.

10. **Consistency.** No more water shall be used than is necessary to produce a concrete which can be worked thoroughly into the forms and around the reinforcing. The consistency shall be measured by the slump test in the method described in the 1921 report of the Committee on Masonry, American Railway Engineering Association. The maximum slump shall not exceed 6 inches. The consistency shall be checked up from time to time.

11. **Mixing.** Mixing shall be done in a batch mixer of approved type, equipped with a suitable charging hopper, water storage, and water measuring device. The entire contents of the drum shall be discharged before recharging. Each batch shall be mixed for not less than 1½ minutes after all the materials are in the mixer, during which time the mixer shall rotate at a peripheral speed of about 200 feet per minute. The volume of the mixed batch shall not exceed the manufacturer's rated capacity. The retempering of concrete which has partially hardened shall not be permitted. In cold weather aggregate shall be heated, if necessary, to remove frost and frozen lumps.

(III) Depositing Concrete

12. **General.** Before depositing concrete the molds shall be thoroughly cleaned and coated with non-staining mineral oil or other approved material. The mixer should be so located that the concrete can be discharged directly into the molds or conveyed to the molds in such a manner as to cause no separation of the ingredients. Each mold shall be completely filled in one continuous operation.

13. **Molds.** Molds shall be substantial, rigid, and true to plan. Metal molds are more satisfactory than wooden molds.

14. **Placing Reinforcing.** The reinforcing shall be securely and continuously held in its proper position in the post during the placing of the concrete and until the post is removed from the mold. Metal spacers that would cause distinct lines of cleavage in the post shall not be used. The reinforcing shall be supported as often as is necessary to prevent its sagging to any appreciable extent due to its own weight or to the weight of the wet concrete.

15. **Compacting.** Concrete shall be thoroughly compacted into the molds and around the reinforcing. This is best accomplished by giving the molds a jogging or vibratory motion during and after depositing.

16. **Finish.** All posts shall have a clean, smooth finish. If any pockets or holes are discovered upon removal from the molds, they shall be immediately filled with a mixture of one part cement to two parts fine aggregate. Pockets or holes more than ½ inch in depth or more than ½-inch in diameter, or any exposure of the reinforcing shall cause the rejection of the post.

(IV) Curing and Handling Posts

17. **Curing.** The posts shall remain in the molds until the concrete has thoroughly hardened and in no event for less than 24 hours after placing. During this time and until they are cured the posts shall be carefully handled and protected from shock. When the posts are removed they shall be stocked in a nearby vertical position and protected from direct sunlight. They shall be kept wet by sprinkling for eight or ten days after being made. They should be cured for not less than 90 days, when cured naturally, before being shipped or set. Posts shall not be cured out of doors during freezing weather.

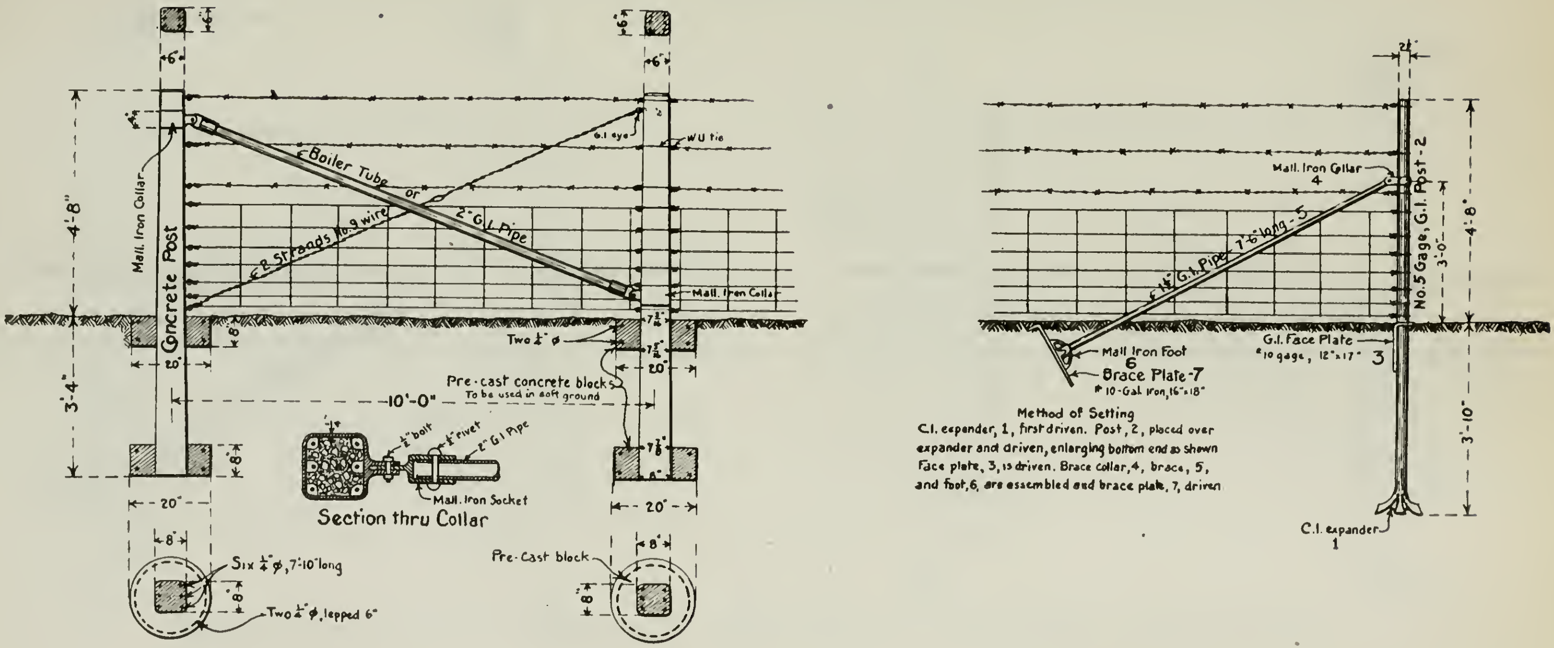
(V) Miscellaneous

18. **Inspection.** All materials and all processes of manufacture shall be subject to inspection and approval at all times. Free access shall be provided for all authorized inspectors to all parts of the plant in which the posts or the materials are made, stored or prepared.

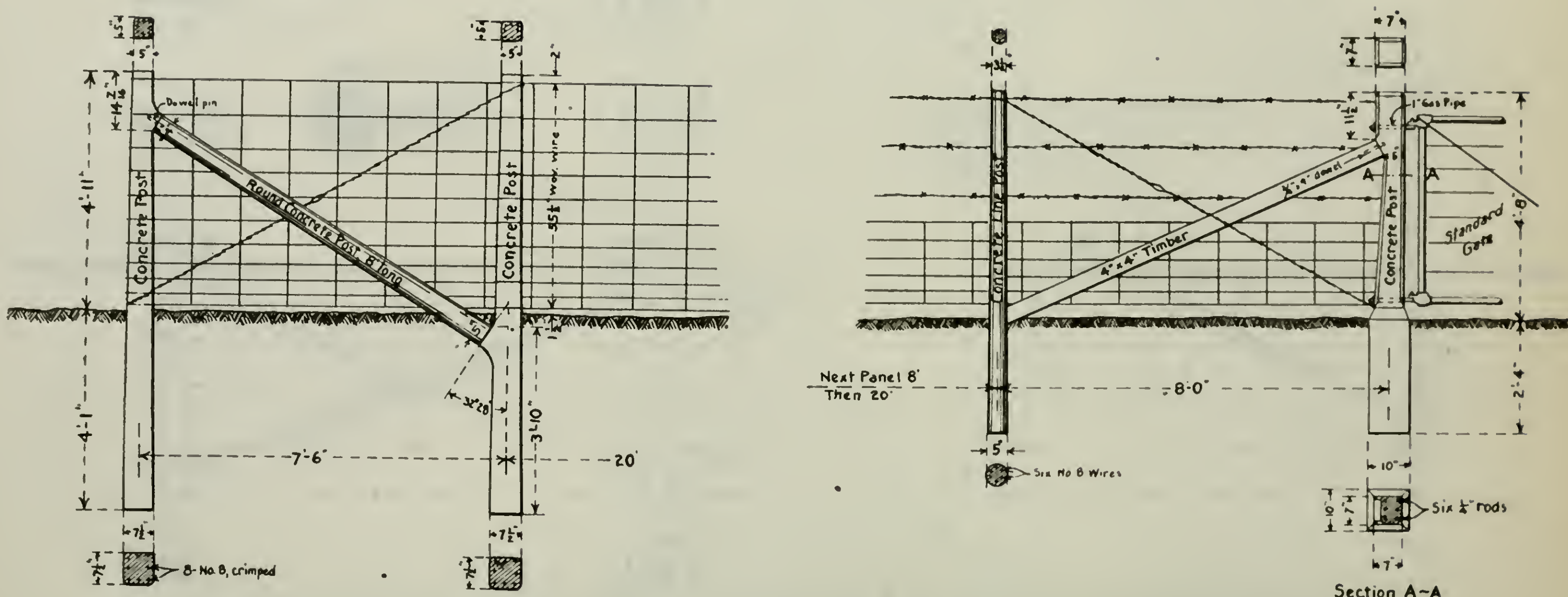
19. **Tests.** All testing of materials used in the manufacture of posts, all preparing, storing and testing of concrete specimens, as provided in Section 8 hereof, and all screen analyses of aggregates, shall be made in accordance with the methods adopted or approved by the American Railway Engineering Association and in effect at the time such tests, analyses, etc., are carried out. In case the American Railway Engineering Association shall not have approved or adopted any methods for such tests, analyses, etc., the same shall be made in accordance with the methods then adopted or approved by the American Society for Testing Materials.

20. **Patents.** The manufacturer or contractor shall pay all royalties for the use of patented designs or devices or forms of construction and protect the Railway Company from all claims of infringements or liability for the use of such patents.

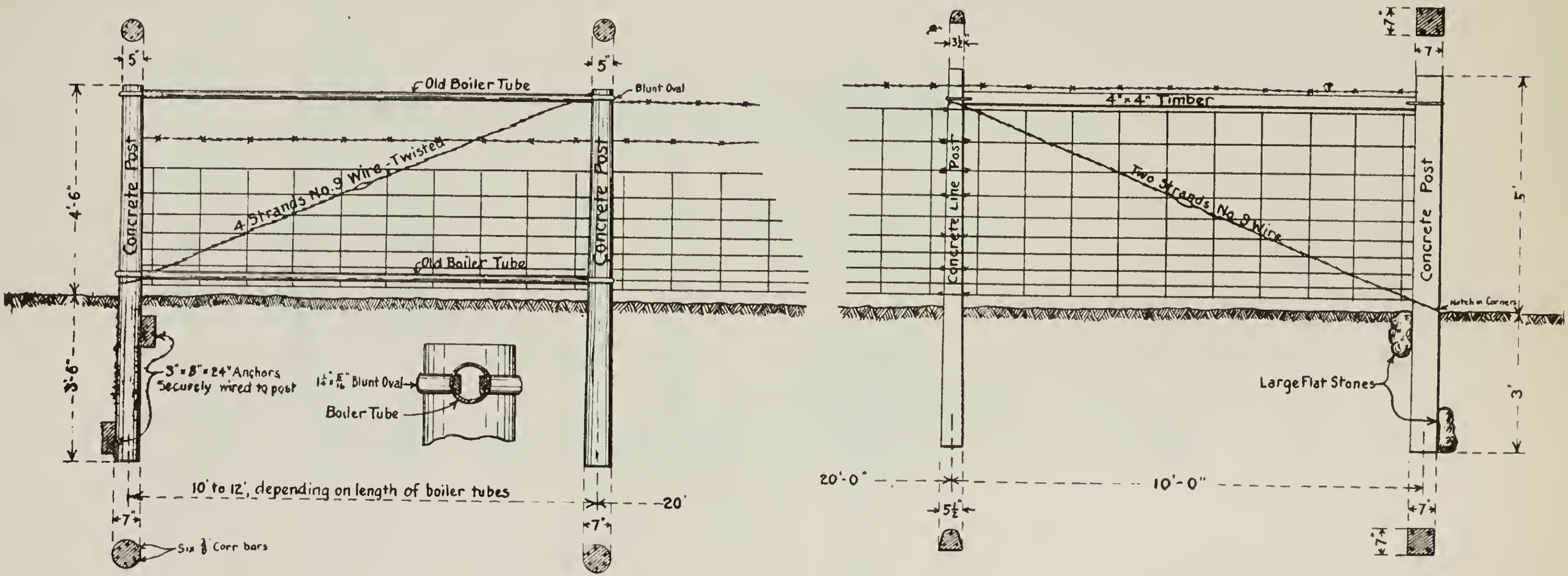
Examples of End Posts and Brace Panels for Right-of-Way Fence with Concrete or Steel Line Posts

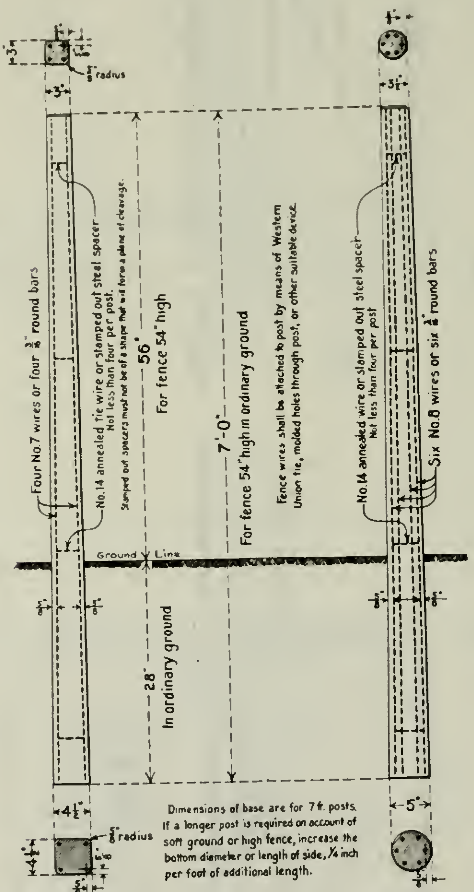


Examples of End Posts and Brace Panels for Right-of-Way Fence with Concrete or Steel Line Posts



Examples of End Posts and Brace Panels for Right-of-Way Fence with Concrete or Steel Line Posts





SQUARE POST ROUND POST

CONCRETE FENCE POSTS

REPORT OF COMMITTEE XIII—WATER SERVICE

A. F. Dorley, *Chairman;*
R. C. Bardwell,
S. C. Beach,
J. H. Davidson,
B. W. DeGeer,
G. B. Farlow,
J. H. Gibboney,
E. M. Grime,
W. C. Harvey,
R. L. Holmes,
H. H. Johntz,
C. H. Koyl,
C. R. Knowles, *Vice-Chairman;*
P. M. LaBach,
E. G. Lane,
Thomas Lees,
M. E. McDonnell,
W. M. Neptune,
W. A. Parker,
E. H. Olson,
A. B. Pierce,
T. D. Sedwick,
F. D. Yeaton,
Committee.

To the American Railway Engineering Association:

Your Committee on Water Service presents below, its report to the Twenty-third Annual Convention on the following subjects:

(1) Revision of the Manual

Report of Sub-Committee on this subject appears in Appendix A.

(2) Supply of Drinking Water on Trains and Premises of Railroads

A progress report on this subject appears in Appendix B.

(3) Specifications for Contracting Water Service Work

The Sub-Committee, to date, has been unable to arrange the data secured on this subject in suitable form for presentation to the Association and desires to report progress.

(4) Effect of Local Deposits on Pollution of Surface or Shallow Well Water Supplies

A collection of typical instances which completes the report on this subject is presented in Appendix C.

(5) Pitting and Corrosion of Boiler Tubes and Sheets

A progress report on this subject is submitted in Appendix D.

(6) Specifications for Various Chemicals Used in Water Treatment

A final report on this subject is submitted in Appendix E for adoption and publication in the Manual.

(7) Centrifugal Pumps for Railway Water Service

A report on this subject appears in Appendix F.

(8) Standard Specifications

At the suggestion of the Standardization Committee and by authority of the Board of Direction, the standard specifications of the American Water Works Association covering cast iron pipe and special castings and hydrants and values are submitted in Appendix G for the approval of this Association.

(9) University Work

Brief reference to work recently done, or now in progress at Universities in connection with water supply problems is given in Appendix H.

CONCLUSIONS

Your Committee requests the following action on its report:

(1) That report of the Sub-Committee be received as information; that the definitions given be approved and inserted in the Manual; and that the subject of examination of the subject-matter in the Manual be again referred to the Committee for further study and report.

(2) That the report on progress of drinking water regulations be received as information and that the subject be reassigned to the Committee for further study and report.

(3) That the subject of specifications for contracting water service work be reassigned to the Committee for further study and report.

(4) That the final report on effect of local deposits on the pollution of surface and shallow well water supplies be received as information.

(5) That the progress report on the study of pitting and corrosion of boiler tubes and sheets be received as information, and that the subject be reassigned to the Committee for further study and report.

(6) That the report on Specifications for the various chemicals used in water treatment be adopted and published in the Manual.

(7) That the report on centrifugal pumps for railway water service be received as information.

(8) That the specifications of the American Water Works Association covering cast iron pipe and special castings, and hydrants and valves be adopted and published in the Manual.

(9) That the reference to work of interest to railway water supply being done at Universities be accepted as information.

Suggested Subjects for Next Year's Study and Report

(1) Study of subject-matter in the Manual with view to recommendations for changes.

(2) Study of progress of regulations of Federal or State Authorities pertaining to drinking water supplies.

(3) Study and final report on specifications for contracting railway water service work.

(4) Study and report on pitting and corrosion of boiler tubes and sheets, taking into consideration the character of the metal used, method of manufacture, construction of boilers, and quality of water.

(5) Study and report on use of oil engines in railway pumping stations.

(6) Study and report on value of water treatment to railroads.

(7) Study and report on standard methods of water analysis and interpretation of results.

(8) Study and report on relative merits of cast iron, steel, wood and other materials for pipe lines.

Respectfully submitted,

Committee on Water Service,,

A. F. Dorley, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

F. D. Yeaton, *Chairman;*
G. B. Farlow,
E. G. Lane,
W. M. Neptune,
H. H. Johntz,
W. H. Parker,
W. C. Harvey,
Sub-Committee.

Due to an oversight, the following definition for a continuous treating plant was omitted last year. The Water Service Committee voted to insert it in the new Manual, because there is a definition for an intermittent treating plant and without a definition for a continuous plant, the definitions would not be complete.

Continuous Plant.—"One so designed that the untreated water may be pumped to it without interruption and where the volume of the chambers through which it passes before flowing to storage is sufficient for complete chemical reaction and precipitation."

The Committee has added the following explanatory note at the bottom of Table 2, shown on page 450 of the 1915 Manual:

"Table is based on use of calcium oxide or lump lime. To obtain equivalent value for hydrated lime, multiply lime value shown in table by 1.32."

Under definitions published in Volume 21 for insertion in the new Manual, the following corrections have been made: Group A, third item, eighth and twenty-second words "strainer" to read "screen," to conform with the sixth item.

Considering the definitions, the word "penstock" has been eliminated in question 23, under "Examination Questions for the Care of Boilers."

The Committee recommends the following additions and changes in the new Manual:

Under Definitions of Terms used in Railway Water Service, Group G, are definitions for single and double-acting pumps. The following definition for a double-stroke pump should be added:

Double-Stroke Deep Well Pump.—One that employs two separate balanced lines of pump rods and attached water pistons. The two lines of pump rods and their respective pistons alternate with each other in such a way that the weight, or load, lifted by each rod is carried only in its tension, or upstroke.

Alkali Water.—A term in common use, meaning water containing in solution any compound of sodium or potassium in appreciable amounts.

Corrosion.—The eating away of the surface of metal by chemical action, either regularly and slowly as by rusting in air, or irregularly and rapidly as by pitting and grooving in the interior of boilers.

Appendix B

STUDY OF PROGRESS OF REGULATIONS OF FEDERAL OR STATE HEALTH AUTHORITIES PERTAINING TO DRINKING WATER SUPPLIES

S. C. BEACH, *Chairman;*
R. C. BARDWELL,
J. H. DAVIDSON,
J. H. GIBBONEY,
M. E. MCDONNELL,
A. B. PIERCE,
T. W. SEDWICK,
Sub-Committee.

In the study of this subject due consideration has been given to published methods and laws promulgated by the United States Public Health Service and the facts and methods ascertained from both published and personal contact with health authorities from the various states in which the railroads operate, together with the sanitary officers now assigned to duty throughout the United States from the Government Health Service co-operating with the state health authorities for betterment of sanitary conditions connected with and maintained by Interstate Carriers. Surveys of several coach yards and the handling of drinking water have already been made by these men.

The revised edition of the Interstate Quarantine Regulations of May, 1921, published by the United States Health Service of the Treasury Department contains information for the guidance of all concerned. The Standard Railway Sanitary Code originally prepared by the Committee on Health and Medical Relief of the United States Railroad Administration, amended by the Conference of State and Provincial Officers of Health, May 25, 1920, and adopted by twelve States up to the present time, is in conformity with the Quarantine Regulations and contains information applicable to the Railways.

The Interstate Quarantine Regulations and Standard Railway Sanitary Code furnish full information on subjects pertaining to railway sanitation and laws governing same and is recommended to the notice of all concerned.

Your Committee desires to call attention to the regulations directing the notification of health authorities as to location of supply points and ownership of sources, this to be done twice yearly with proper certification and permission of Surgeon General for use of water on Interstate Carriers. The posting of signs forbidding use of water considered unsafe for public use in now done by Federal or State health authorities and notice is signed either by the United States Public Health Service, or the State health authorities or both, thus relieving the railroads of this responsibility. The collection of water samples from indicated sources of supply is performed in most of the States by the State health authorities, the iced containers being shipped by the railroads to the State Laboratories for analysis. The examination is usually without cost to the railroad.

Section 19, Subdivision (d), Interstate Quarantine Regulation, provides that drinking water shall be handled in such a manner as not to impair its sanitary quality or safety and already surveys have been made by State and Federal health authorities tending towards the attainment of betterment in methods of handling now being followed, their recommendations being directed towards the cleanliness of drinking water coolers, containers used in carrying water from source to coolers, and directing that ice shall not come in contact with water. This latter provision, it will be noted, is not in accordance with an already existing provision that properly handled ice shall not necessarily be kept separated from water until July 1, 1922, and in accordance with recently received information contained in Circular No. 2131, Medical and Surgical Section, American Railway Association, and dated March 7, 1921, an enforced separation of ice and water has been postponed until July 1, 1924.

Instructions are also given that containers shall be cleaned once each week and that storage tanks shall be flushed and drained once a month; hose used in filling containers shall have a protected metal nozzle kept clean by flushing and washing.

Circlar No. 2140 of the American Railway Association contains, among other matters, a letter written by Assistant Surgeon General McLaughlin, "that if permission to use water is given a community by the State having jurisdiction the use of such water by a carrier should be permitted." This brings up the question of temporary provisional certification, which is for water not fully approved by reason of a by-pass in the water system, connection with impure water supply for emergency use, unsatisfactory operation or similar reasons, the intent and purpose of such certification being to give opportunity for advised and needed repairs or improvements. This matter was taken up with the United States Public Health Service and it was stated that a ruling covering provisional certification would be contained in the revised edition Interstate Quarantine Regulations, which, however, was omitted.

The action of the Government Health Service in giving closer supervision to the sanitary conditions of the railroads by surveys and reports, is significant of the movement now gaining headway, and a positive knowledge of laws and regulations promulgated for the governance of railway sanitation is of interest. As examples of activity of recent origin, there might well be mentioned a survey of Chicago coach yards with report and recommendation by a Government Sanitary Engineer. Your Committee have perused this report and find it contains a survey of existing conditions with recommendations as to remedial measures.

Representatives of the Government Health Service are obtaining samples of drinking water from trains. The results of this methodical examination of the waters are yet to be seen.

The appointment of a Joint Committee from the Medical and Surgical Section, also the Mechanical Section, of the American Railway Association and from the Water Service Committee of the American Railway Engineering Association, is looked upon as a valuable forward step in the splendid efforts which the railroads are putting forth to give the public their best, in service, in equipment and in courtesy, and the resultant action is looked forward to by all. Consideration will also be given by this Joint Committee to the establishment of laboratories for the analysis of water samples and other laboratory work of an essential and necessary kind and while some of the railroads have such laboratories already established and of great service to their respective roads, it is possible that a general movement in this direction will serve to emphasize the efforts put forth in the past to co-operate with and assist the United States Public Health Service and their Interstate Health Officers as well as the State Health authorities in all the States traversed by railroads.

Appendix C

EFFECT OF LOCAL DEPOSITS ON POLLUTION OF SURFACE AND SHALLOW WELL WATER SUPPLIES

R. L. Holmes, *Chairman;*
R. C. Bardwell,
J. H. Gibboney,
C. R. Knowles,
P. M. LaBach,
T. W. Sedwick,
B. W. DeGeer,
M. E. McDonnell.
Sub-Committee.

Typical Instances

Effect Upon Surface Supply

(a) Coal Mines—The effect of waste and drainage from coal mines upon surface supplies is apparent and unfortunately too common to necessitate a detailed description. The possibility of such pollution must always be considered when establishing a permanent water station in the vicinity of coal fields.

(b) Coal Storage—The effect of drainage from coal storage pollution is similar to that from coal mine drainage and when storing this commodity precautions should be taken to prevent contamination of water supply.

The accompanying sketch map Exhibit "A" illustrates how surface water may become contaminated by storing coal upon the watershed of a reservoir. Analysis E shows the effect of seepage (seventeen days later) upon the water in the lower pond. No inflow was permitted through spillway connecting the ponds, a new outlet having been provided on and around the eastern side of lower pond.

(c) Cinders—The passage of water through cinder deposits releases sulphuric acid or its equivalent to a much greater extent than drainage from coal storage. Instances have been cited where water has been grossly contaminated in a reservoir by drainage from a cinder embankment and also at a point where it was necessary to haul water and same was allowed to flow to a creek through a cinder fill as it was being unloaded.

(d) Oil Well Waste—In the drilling of oil wells water heavily impregnated with salt is usually encountered. In the operation of these wells large amounts of this water is wasted into streams and natural water courses making these supplies utterly unfit for boiler purposes.

The following analyses show mineral content prior to and after controlling the oil well waste and the installation of the sanitary sewer system in the City of Ranger, Texas, population at that time about 25,000.

Analyses

December, 1919	*Grains per U. S. Gallon*	*Septmber*, 1920	*Grains per U. S. Gallon*
Organic Matter	35.00		2.04
Silica	1.87		1.69
Iron Oxide and Alumina	1.17		0.12
Calcium Carbonate	0.00		3.55
Mag. Carbonate	6.71		0.80
Calcium Sulphate	3.74		1.36
Calcium Chloride	50.56		0.97
Sodium Chloride	182.51		6.10
Total	281.56		16.63

(e) Sewage and Industrial Waste—Two marked examples of this form of pollution occur in the Calumet River near Chicago and the Schuylkill River near Philadelphia. Where it is necessary for railroads to use water from such supplies, considerable trouble is experienced at certain periods of each year. Where the pollution cannot be diverted the only alternative lies in restricting the contamination to flood stages where the dilution will greatly minimize the trouble.

(f) Mud and Cultivation—The information secured by your Sub-Committee is so meager that it is hardly possible to make a concrete statement of facts. However, we have some reports, especially those from the Central Western section of the United States that reservoirs of small capacity (50 to 150 acre feet) have been abandoned after 15 to 18 years of service, caused by silting which reduced the capacity to where they would not have a sufficient supply to carry through a drouth period.

The life of a reservoir depends largely upon the slope and character of soil of catchment area and the extent of cultivation thereon.

Effect On Wells—Storage Coal and Cinder Deposits.

(a) Storage Coal—A typical example of this form of pollution occurred at a terminal of a Middle Western railroad. The water supply was secured from two gravel wall wells, 44 feet in depth.

The water was first a carbonate water of 14 grains temporary hardness.

About 40,000 tons of coal was stored within a radius of one half mile and three months later considerable flue and boiler trouble started.

Examination of the water showed a decrease of seven grains in temporary hardness and an increase to twenty-eight in permanent hardness. Test of drainage water in pools around coal piles showed high sulphate content.

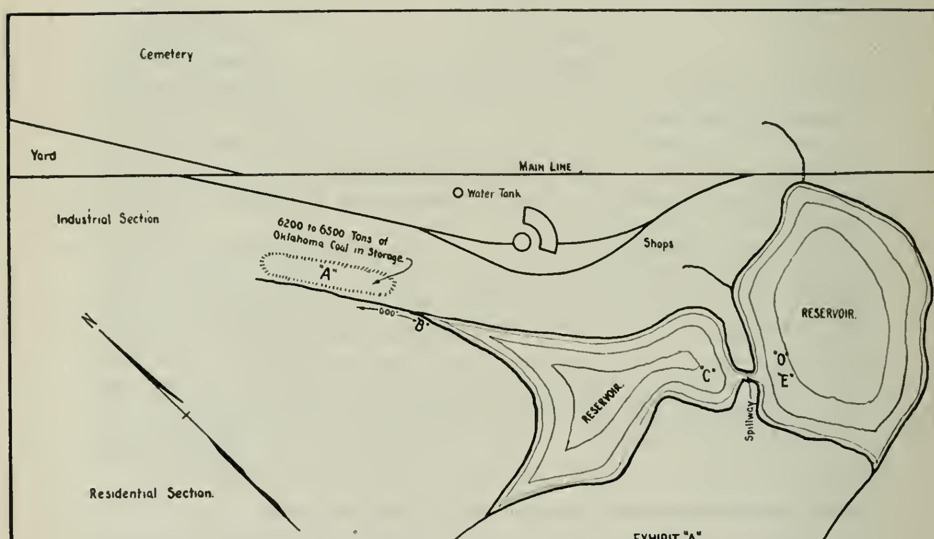
After every rain since storing coal at this location began, there has been an increase in sulphate hardness of the well water, sometimes as much as sixty grains. Relief has been secured by going to a river supply three-fourth miles away.

(b) Cinder Deposits—The most interesting report that we are able to obtain in this connection will be found on pages 1215 and 1216, May 16, 1919, issue of Railway Age, by William M. Barr.

This article illustrates the importance that should be attached to local ground conditions when developing new water supplies, even when the water comes from considerable depth.

CONCLUSIONS

It should be the duty of every one connected with the Water Department to match closely and protect against all chances of pollution.



ANALYSES. GRAINS PER U.S GALLON.	A	B	C	D	E
ORGANIC MATTER	2.92	5.60	2.97	3.21	1.17
SILICA	43.75	21.58	0.58	1.17	0.58
IRON OXIDE	T			1.11	
MAGNESIUM SULPHATE	50.44	17.75	4.74	3.28	2.65
CALCIUM " "	42.06	21.81	12.93	8.57	4.21
SODIUM " "			10.79	11.89	8.52
" CHLORIDE	5.78	5.78	2.40	9.15	5.11
IRON SUL.+ COL. IRON.	1679.46	661.13			
SULPHURIC ACID	607.70	142.92	8.46		1.84
FERRIC SULPHATE			17.79		3.94
TOTAL	2432.11	876.57	60.66	38.18	28.02

EXHIBIT "A"

SKETCH SHOWING LOCATION OF TESTS FOR POLLUTION OF WATER. CAUSED BY THE STORAGE OF COAL.

Appendix D

STUDY AND REPORT ON PITTING AND CORROSION OF BOILER TUBES AND SHEETS, CHARACTER OF METAL, METHODS OF MANUFACTURE, CONSTRUCTION OF BOILERS AND QUALITY OF WATER CONSIDERED

M. E. McDonnell, *Chairman;*	P. M. LaBach,
R. C. Bardwell,	B. W. DeGfer,
J. H. Davidson,	Thomas Lees,
J. H. Gibboney,	E. H. Olsen,
T. W. Sedwick,	C. R. Knowles,
C. H. Koyl,	*Sub-Committee.*

An examination of technical literature discloses that discussion of this subject has been in progress for the last sixty years without any definite conclusion having been reached either as to the cause or prevention of pitting and corrosion.

In the meantime the power on railroads has increased tremendously both in first cost and in service required so that it has become of increased importance in the economical handling of traffic that suitable means be found for the prevention of pitting and corrosion of boilers with the incident losses that are involved.

It cannot be expected that this Committee can find the solution in a short space of time and this report is submitted as a progress report only. The following is a brief resumé of the chemical aspects in connection with pitting and corrosion:

The corrosion of steel and iron boiler tubes and sheets is believed to be the result of electro-chemical reactions. Iron, in contact with an electrolyte containing hydrogen ions, goes into solution as iron ions, thereby displacing hydrogen ions, which are liberated as molecular hydrogen. When water does not contain constituents which combine with the iron ions, a state of equilibrium soon results before the boiler tubes and sheets are perceptibly injured. When the water contains certain other constituents such as oxygen and carbon dioxide, the iron ions are removed as oxides or hydroxides, whereby the equilibrium of the solution is disturbed, and more iron goes into solution. A cycle is thereby established which may be rapidly destructive. The ultimate product of destruction is iron oxide, and it proceeds as fast as hydrogen is liberated. The rate of corrosion is a function of electromotive force and resistance of circuit. It is also a function of the active impurities in the water which combine with metallic ions, producing a magnetic oxide which forms a coating on the iron or steel surface which is entirely different physically from the voluminous hydrated precipitates resulting when oxygen or carbon dioxide is present. Free acids ionize in solution, yielding hydrogen ions and an anion radical or element which will combine with ionized iron in the absence of oxygen or carbon dioxide, thereby causing corrosion.

It follows that if the electromotive force could be reduced to zero, no corrosion would result, that if the difference of potential between two parts of a boiler were uniform, the corrosion would be uniform, and that local differences in potential may cause pitting or grooving. Fragments of mill scale adhering to or rolled into steel will set up a difference of potential at local spots, which when immersed in boiler water containing hydrogen ions and other elements capable of combining with diferrion, will cause pitting. Similar results follow the presence of other occlusions sometimes present in segregated steel, or in iron containing small inclusions of soft steel. Repeated alternate bending of a boiler sheet across one axis sets up a difference of potential along a corresponding line on the sheet. Corrosion starts along this line, and any protective coating, such as scale or magnetic oxide of iron, is kept broken by the bending operations, keeping clean metal exposed to the electrolyte. This eventually leads to grooving, unless the cycle of destruction is broken.

The following questionnaire was prepared at the Committee meeting in Chicago on May 6, 1921. This questionnaire was sent to all members of the Sub-Committee and replies were received from nine of the eleven members:

(1) *What In Your Experience Have Been the Causes of Corrosion?*

The experience of the Committee indicates that *general* corrosion is prevalent where acid waters, or waters with a high percentage of chloride or sulphate hardness are used without treatment.

(2) *What In Your Experience Has Been the Cause of Pitting?*

The replies indicate that pitting in locomotive boilers results from electrolytic action, the underlying causes of the electrolytic action being due to chemical or mechanical action or both.

The presence in the water of an electrolyte such as sodium sulphate or sodium chloride is necessary in sufficient quantities to convey the electric current between spots of impurities in the material which have different potentials, thereby resulting in a wasting of the metal at the negative pole. The presence of dissolved oxygen in the water materially assists the electrolytic action by removing the corrosion by-products and allowing the destructive action to continue.

(3) *What In Your Experience Has Been the Cause of Grooving?*

The causes of grooving are also ascribed to electrolytic action. The strained metal of a boiler plate that is not completely covered by a rivet head becomes eaten away or perhaps a plate becomes strained at a point by temperature stress, and the strained streak is corroded. In each case the strained metal is of greater corrosibility and it acts as one of the plates of an electric battery, in which the other plate of the battery is the unstrained metal of the boiler shell and the electrolyte is the water in the boiler.

(4) *What Is Your Method of Prevention?*

To date efforts toward prevention of corrosion, pitting and grooving have been chiefly confined to chemical treatment of the water. No means of complete prevention have as yet been found although in actual practice the trouble has been very materially decreased on some railroads by maintaining a caustic alkalinity in the boilers which appears to have an inhibitive effect on the corrosive action. Apparently, little work has been done toward improving the character of boiler materials and methods of handling with a view to securing a more homogeneous material and eliminating strains and stresses which appear to be responsible in part at least for much of the grooving, ring pitting and similar forms of corrosion.

(5) *Have You Laboratory Tests Confirming Specific Causes of Corrosion, Pitting and Grooving?*

Laboratory tests were reported which indicated that pitting takes place in commercial boiler steel immersed in water very readily where oxygen and carbon dioxide are present and is accentuated by increased amounts of sodium sulphate or sodium chloride and also by higher difference of potential with an increased rate of electrolysis. It is also shown that this action is inhibited to a considerable extent by the addition of sodium carbonate or caustic soda. Other tests were presented which strongly indicated the presence of spots of impurities which had been rolled into the material and made up into flues.

It was brought out in Committee meeting that there is a marked difference in potential between material as originally furnished and that which had been subjected to strains and stresses during fabrication changing the crystalline structure of the metal. Attention was also called to advanced stages of corrosion of some material which had been affected by exposure to atmospheric conditions before being applied to boilers.

(6) *Have You Any Laboratory Tests to Suggest to Confirm Your Findings or That Would Be of Assistance In the Study of This Subject?*

Inasmuch as it has been found in practice, that treatment with caustic soda inhibits to a greater or lesser extent the pitting action, it is suggested that during the coming year careful tests be made to determine the minimum and maximum effective limit of caustic soda treatment with special relation to varying concentrations of sodium sulphate and sodium chloride, these being the principal electrolytes found in boiler waters.

This subject in general is intimately connected with departments other than engineering and it is respectfully suggested that the Board of Direction request that a committee be appointed from the mechanical section to work in coöperation with this committee, so that all phases including the manufacture and fabrication of material may be considered as well as the character of the water supply.

The photographs shown in Exhibits B and C are typical of conditions now occurring on railroads throughout the country.

Exhibit B

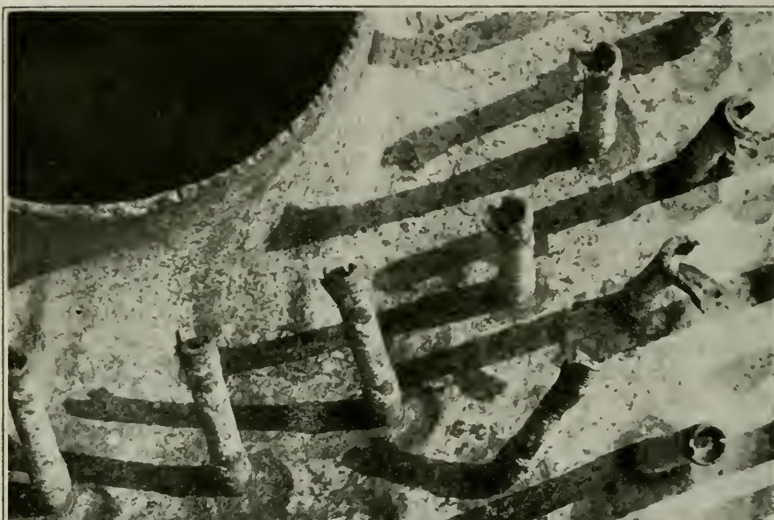
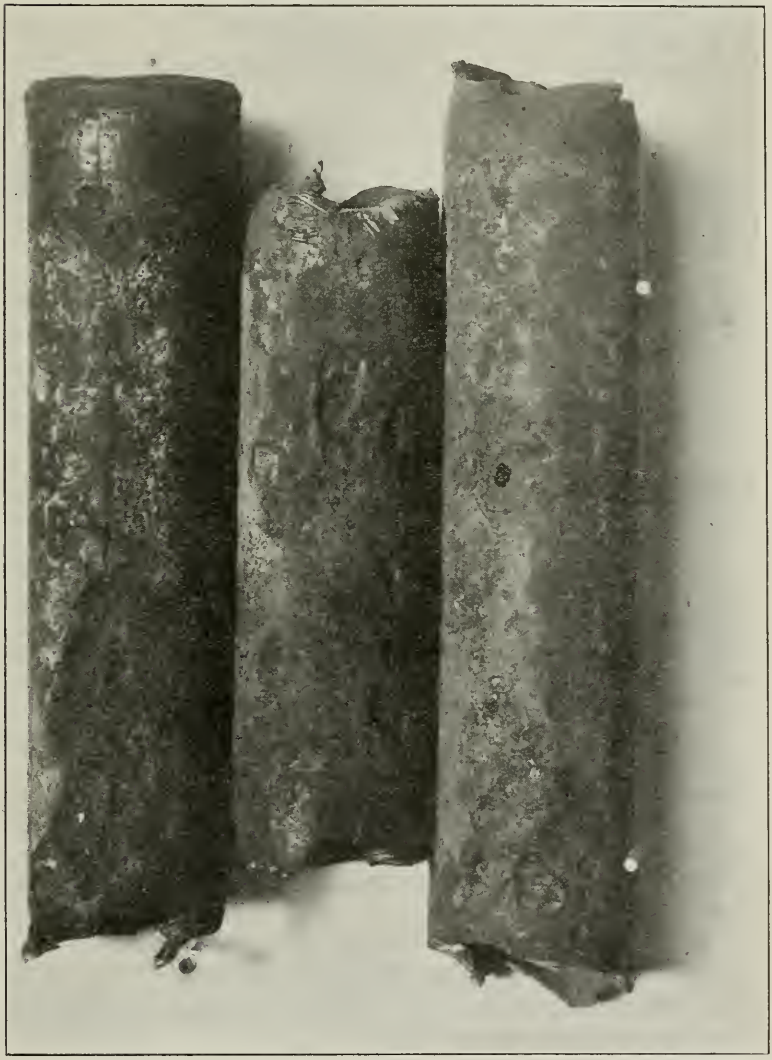


Exhibit C



Appendix E

STUDY AND REPORT ON SPECIFICATIONS FOR VARIOUS CHEMICALS USED IN WATER TREATMENT

P. M. LaBach, *Chairman;*
R. C. Bardwell,
B. W. DeGeer,
J. H. Davidson,
J. H. Gibboney,
C. R. Knowles,
C. H. Koyl,
W. A. Parker,
Sub-Committee.

W. S. C. 1.

STANDARD SPECIFICATIONS FOR SODA ASH TO BE USED IN WATER TREATMENT

Definition.

1. Soda ash is the anhydrous normal carbonate of soda.

Classes.

2. Soda ash is commercially divided into two classes:
(a) Light; (b Dense.

3. Dense soda ash shall be rejected

(I) Chemical Properties and Tests.

Sampling.

4. The samples shall be a fair average of the shipment, and shall be taken from the surface to the center of package.

The vendor shall take a one pound sample from four packages in various locations in each carload or less and forward to the purchaser. The sample, on receipt by the purchaser, shall be immediately transferred to air-tight containers in which the unused portion shall be stored until the soda ash has been finally accepted or rejected by the purchaser.

Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties.

5. (a) The classes and properties of soda ash shall be determined by standard methods of chemical analysis.

(b) Soda ash shall conform to the following requirements as to chemical composition:

Normal sodium carbonate—95 per cent. minimum.

(II) Physical Properties and Tests.

6. The material shall be in dry powdered form and shall be free from lint, chips, ash or other foreign matter.

Fineness.

7. A 100 gram sample shall not have more than 0.5 per cent. by weight, insoluble in cold distilled water.

(III) Packing and Marketing.

Packing.

9. Soda ash shall be packed in cloth or duck bags of not more than 100 lb. net weight, or in paper bags of not more than 50 lb. net weight.

Marking.

10. The name of manufacturer and net weight shall be plainly marked on each package, or attached by tag thereto.

(IV) Inspection, Penalization and Rejection.

Inspection.

11. (a) All soda ash shall be subjected to inspection.

(b) The soda ash may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The Inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the soda ash ordered. The manufacturer shall afford the Inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance, penalization or rejection of the soda ash in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization.

12. All prices shall be based upon the percentage of normal sodium carbonate. If a lower grade is furnished than the one specified, provided it is not less than 80 per cent sodium carbonate, it may be accepted by the purchaser upon the vendor making a rebate equal to percentage of sodium carbonate below the minimum designated.

Rejection.

13. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within 10 working days from the taking or receipt of samples by the purchaser.

(b) Rejected soda ash shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing.

14. Samples which represent rejected soda ash shall be preserved in air-tight containers for 10 working days from the date of test report. In case of dissatisfaction with the result of the tests, the manufacturer may make claim for a rehearing within that time.

W. S. C. 2.

STANDARD SPECIFICATIONS FOR HYDRATED LIME TO BE USED IN WATER TREATMENT

Definition.

1. Hydrated lime is a dry flocculent powder resulting from the hydration of quicklime.

Classes.

2. Hydrated lime for water treatment is commercially divided into two classes:

(a) High-Calcium;
(b) Calcium.

Basis of Purchase.

3. The particular class of hydrated lime desired shall be specified in advance by the purchaser. Unless otherwise specified high-calcium lime shall be furnished.

(I) Chemical Properties and Tests

Sampling.

4. The sample shall be a fair average of the shipment. Three per cent. of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. A 2-lb. sample to be sent to the laboratory shall immediately be transferred to an air-tight retainer, in which the unused portion shall be stored until the hydrated lime has been finally accepted or rejected by the purchaser. Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties.

5. (a) The classes and chemical properties of hydrated lime shall be determined by standard methods of chemical analysis.

(b) The hydrated lime shall conform to the following requirements as to chemical composition:

High Calcium..Not less than 90 per cent Calcium Hydroxide ($Ca(OH)_2$)
Calcium ....Not less than 85 per cent Calcium Hydroxide ($Ca(OH)_2$)

(II) Physical Properties and Tests

Fineness.

6. A 100-gram sample shall leave by weight a residue of not over 2 per cent. on a standard 100-mesh sieve and not over 0.5 per cent. on a standard 20-mesh sieve.

(III) Packing and Marking

Packing.

7. Hydrated lime shall be packed either in cloth or in paper bags of not more than 50 lb. net weight.

Marking.

8. The weight shall be plainly marked on each package, together with the name of manufacturer.

(IV) Inspection, Penalization and Rejection

Inspection.

9. (a) All hydrated lime shall be subject to inspection.

(b) The hydrated lime may be inspected either at the place of manufacture or the point of delivery, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the hydrated lime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the hydrated lime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization.

10. All prices shall be based upon the minimum percentage of calcium hydroxide. If a lower grade is furnished than the one specified it may at the option of the purchaser be accepted upon making a rebate equal to the percentage of calcium oxide below the minimum designated.

Rejection.

11. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples.

(b) Rejected hydrated lime shall be returned to the shipper or as he may direct. All freight charges to be paid by the shipper in both directions.

Rehearing.

12. Samples which represent rejected hydrated lime shall be preserved in air tight containers for ten working days from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

W. S. C. 3.

STANDARD SPECIFICATIONS FOR QUICKLIME TO BE USED IN WATER TREATMENT

Definition.

1. Quicklime for use in water treatment is a material the major part of which is calcium oxide, which will slake on the addition of water.

Grades.

2. Quicklime is divided into two grades:

(a) Selected.—Shall be well-burned, picked free from ashes, coke, clinker or other foreign material.

(b) Run-of-Kiln.—Shall be well-burned, without selection. It shall be free from large lumps of unburned or foreign material.

Forms.

3. Quicklime is shipped in two forms:

(a) Lump.—Shall be kiln size.

(b) Pulverized.—Shall be reduced in size to pass a ¼-in. screen.

Classes.

4. Quicklime for water treatment is divided into two classes:

(a) High-Calcium.

(b) Calcium.

Basis of Purchase.

5. The particular grade, form and class of quicklime desired shall be specified in advance by the purchaser. Unless otherwise specified high-calcium quicklime shall be furnished.

(1) Chemical Properties and Tests

(A) Sampling

Lime in Barrels.

6. Quicklime shall be shipped in barrels, or other containers of similar size. At least 3 per cent. of the number of barrels shall be sampled. They shall be taken from various parts of the shipment, dumped, mixed and sampled. The samples shall comprise at least 10 shovelsful taken from different parts of the shipment. The total sample taken shall weigh at least 100 lb. and shall be crushed to pass a 1-in. ring, and quartered to provide a 15-lb. sample for the laboratory.

Laboratory Samples.

7. All samples to be sent to the laboratory shall be immediately transferred to an air-tight container in which the unused portion shall be stored until the quicklime shall finally be accepted or rejected by the purchaser.

Check tests on samples taken from car at destination will occasionally be made, and should agree within reasonable limits with initial sample.

(B) Chemical Tests

Chemical Properties.

8. (a) The classes and chemical properties of quicklime shall be determined by standard methods of chemical analysis.

(b) Samples shall be taken as specified in sections 6 and 7.

(c) Quicklime shall conform to the following requirements as to chemical composition:

Chemical Composition

Properties Considered	High-Calcium		Calcium	
	Selected	Run-of-Kiln	Selected	Run-of-Kiln
Calcium Oxide, per cent	90 (min.)	90 (min.)	85–90	85–90
Calcium Oxide plus Magnesium Oxide, min., per cent	90	85	90	85
Carbon Dioxide, max., per cent	3	5	3	5
Silica plus Alumina plus Oxide of Iron, max., per cent	5	7.5	5	7.5

(II) Inspection, Penalization and Rejection

Inspection.

9. (a) All quicklime shall be subject to inspection.

(b) The quicklime may be inspected either at the place of manufacture or the point of delivery, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works, which concern the manufacture of the quicklime ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the quicklime in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization.

10. All prices shall be based upon minimum percentage of calcium oxide. If a lower grade is furnished than the one specified it may, at the option of the purchaser, be accepted upon making a rebate equal to the percentage of calcium oxide below the minimum designated.

Rejection.

11. (a) Unless otherwise specified, any rejection based on failure to pass the tests prescribed in these specifications shall be reported within ten working days from the taking or receipt of samples.

(b) Rejected quicklime shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing.

12. Samples which represent rejected quicklime shall be preserved in air-tight container for ten working days from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

W. C. S. 4.

STANDARD SPECIFICATIONS FOR SULPHATE OF ALUMINA TO BE USED IN WATER TREATMENT

Definition.

1. This chemical shall be the commercial product known as Basic Sulphate of Alumina.

(I) Chemical Proportion and Tests

Sampling.

2. The sample shall be a fair average of the shipment. Five per cent of the packages shall be sampled. The sample shall be taken from the surface to the center of the package. A five-pound sample shall be sent immediately to the laboratory and transferred to an air-tight container in which the unused portion shall be stored until the alumina has been finally accepted or rejected by the purchaser.

Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties.

3. (a) The chemical proportion of basic sulphate of alumina shall be determined by standard methods of chemical analysis.

(b) Basic sulphate of alumina shall contain not less than 17 per cent. water soluble aluminum oxide (Al_2O_3); 3 per cent by weight of the aluminum oxide shall be in excess of the theoretical amount required to combine with the sulphuric acid present.

(II) Physical Properties and Tests

4. The material shall be in dry lump form and shall be free from lint, chips, ash or other foreign matter.

(III) Packing and Marking

5. Basic sulphate of alumina shall be packed in cloth or duck bags of not more than 50 lb. net weight, or in barrels or containers of not more than 300 lb. net weight.

6. The name of manufacturer, net weight and percentage of water soluble alumina shall be plainly stencilled on each end of package or marked on tag securely attached thereto.

(IV) Inspection, Penalization and Rejection

7. (a) All basic sulphate of alumina shall be subjected to inspection.

(b) It may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the sulphate of alumina ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance, penalization or rejection of the alumina in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Penalization.

8. All prices shall be based upon the percentage of water soluble aluminum oxide.

If a lower grade is furnished, it may be accepted at the option of the purchaser, provided the deficiency does not exceed one per cent. The contract price to be reduced in the ratio of the deficiency to the 17 per cent of water soluble aluminum oxide specified.

Rejection.

9. (a) Unless otherwise specified, any rejection based on failure to pass tests presented in these specifications shall be reported within ten working days from the taking or receipt of sample by the purchaser.

(b) Rejected basic sulphate of alumina shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing.

10. Samples which represent rejected basic sulphate of alumina shall be preserved in air-tight containers for ten working days from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

W. S. C. 5.

STANDARD SPECIFICATIONS FOR SULPHATE OF IRON TO BE USED IN WATER TREATMENT

Definition.

1. Sulphate of iron is the ferrous sulphate, the theoretical formula of which is $Fe\,SO_4 + 7H_2O$.

Classes.

2. Sulphate of iron commercially does not have exactly seven molecules of water combined with one molecule of anhydrous ferrous sulphate.

3. Commercially there are three grades:

(a) Prime green, selects, or stick crystals.
(b) Seconds or bottoms.
(c) Granular or sugar sulphate of iron.

(I) Chemical Properties and Tests

Sampling.

4. The samples shall be a fair average of the shipment and shall be taken from the surface to center of each package.

Ten one-pound samples shall be taken from packages in various locations in each carload or less. These samples shall be thoroughly mixed, and then quartered. One-quarter shall then be placed in an air-tight container and submitted to the purchaser's laboratory for tests.

Check tests on samples taken from cars at their destination will occasionally be made, and should agree within reasonable limits with initial sample.

Chemical Properties.

5. (a) The chemical properties of the material shall be determined by standard methods of analysis, and the shipments shall conform to the following minimum requirements:

(b) Impurities: Not over 2 per cent.
(c) Anhydrous ferrous sulphate $Fe\,SO_4$: Not less than 53.5 per cent.
(d) Free Sulphuric Acid: Not over .025 per cent.

(II) Physical Properties and Tests

Physical Properties.

6. Shipments of seconds or bottoms shall be rejected. Either Grade (a) or Grade (c) shall be furnished as specified on the purchase order. Unless otherwise specified, Grade (c) shall be furnished.

(III) Packing and Marking

Packing.

7. Sulphate of iron shall be packed in cloth or duck bags of not more than 100 lb. net weight, or in barrels or containers of not more than 250 lb. net weight as specified in purchase order.

Marking.

8. The name of the manufacturer, net weight and grade of sulphate of iron shall be stencilled on each package, or marked on tag securely attached thereto.

(IV) Inspection and Rejection

Inspection.

9. (a) All sulphate of iron shall be subjected to inspection.

(b) The sulphate of iron may be inspected at the place of manufacture or point of delivery, or both, as arranged at the time of purchase.

(c) The inspector representing the purchaser shall have free entry at all times, while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the sulphate of iron ordered. The manufacturer shall afford the inspector all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the operation of the works.

(d) The purchaser may make the tests to govern the acceptance or rejection of the sulphate of iron in his own laboratory or elsewhere. Such tests, however, shall be made at the expense of the purchaser.

Rejection.

10. (a) Unless otherwise specified, any rejection based on failure to pass tests prescribed in these specifications shall be reported within 10 working days from the taking or receipt of samples by the purchaser.

(b) Rejected sulphate of iron shall be returned to the shipper or as he may direct. All freight charges in both directions to be paid by the shipper.

Rehearing.

11. Samples which represent rejected sulphate of iron shall be preserved in air tight containers for 10 working days from the date of test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

Appendix F

REPORT ON CENTRIFUGAL PUMPS FOR RAILWAY WATER SERVICE

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Historical

The first centrifugal pump was invented by Denis Papin of Hesse, Germany, about 1703 or 1704. This was followed by a centrifugal pump described by Ewbanks as "a straight tube attached in an inclined position to a vertical axis and whirled around by the handle." The invention of this pump is credited to M. LeDemour, who sent a description of it to the French Academy in 1732.

While the description of these earlier pumps is rather vague, it is evident that they bore but little resemblance to the modern centrifugal pumps. There is no record of their being used to any great extent, except perhaps as mechanical novelties.

There was but little development of the centrifugal pump for over a hundred years after it was invented or until about 1818 when what was known as the Massachusetts pump was brought out. This pump while crude as compared to modern pumps showed great improvement over the earlier pumps and it appears to have been used satisfactorily for a number of years.

Further development followed the production of the Massachusetts pump. The principal improvements being those of Andrews in 1839; Bessemer in 1845; Appold in 1848 and those of Gwynne in 1851. There followed considerable interest and some further development for a few years, after which there was but little improvement in design until the beginning of the Twentieth Century when engineers and pump designers began to realize that a pump capable of much higher heads and greater efficiency than those in general use could be developed. The development was then quite rapid as compared with the former history of the pump and within the past few years the centrifugal pump has been recognized as a formidable competitor of the reciprocating pump.

Principles of Operation

A centrifugal pump consists essentially of an outer shell or casing within which revolves an impeller mounted on a shaft. The water enters the impeller at its center and passes out through the vanes into the casing and from the casing to the discharge pipe. The water enters the impeller at a low velocity but passes out from the impeller at an increasing velocity until it reaches its maximum as it passes out of the impeller.

The velocity at which the water leaves the impeller depends upon the speed and diameter of impeller, form of vanes and area of openings. As the water enters the casing and discharge the velocity is decreased on account of the increased area and is changed into pressure.

The velocity of the water upon leaving the impeller determines the theoretical head against which it may be delivered by the pump. The efficiency and actual head against which the pump will deliver the water will depend upon the design and construction of the pump, particularly with regard to the impeller and diffusion space.

Impellers

Impellers are of two general forms known as the open and closed type. An open impeller consists of radial vanes attached to a hub and disk; the vanes are open at the sides and revolve between the two fixed sides of the pump. In a closed impeller the vanes are carried between two disks. It is apparent that the friction loss must be greater with the open type of impeller as the water is revolved against the sides of the pump at approximately the same velocity as the impeller With the closed impeller the frictional loss is confined to the water passing through the vanes and to the impeller revolving in the surrounding water. Therefore, it is possible to obtain much better efficiency with the closed impeller and it is generally used in types of pump adapted to railway water service.

The principal friction loss in any type of centrifugal pump is that of the impeller and the friction loss by the open impeller is twice that of the closed impeller. This loss together with the leakage loss causes it to be less efficient than the closed impeller type as far as the handling of clear water is concerned. It is therefore, recommended only for handling large volumes of water at low head and where conditions are such that debris might cause trouble by reason of clogging the smaller passageways of a pump of more efficient design.

The open impeller, volute type was about the first successful design of centrifugal pump and until the year 1900 it was practically the only pump of this kind in use. Since that time theory and practice have developed more efficient types of centrifugal pumps, particularly the enclosed impeller volute and the turbine type.

Turbine and Volute Pumps

For convenience centrifugal pumps may be divided into two general classes or types: Turbine and Volute pumps.

Turbine pumps have circular casings and diffusion vanes surrounding the impeller. The function of the diffusion vanes is to reduce the velocity of the water upon leaving the impeller through gradually enlarging passages, efficiently transforming the velocity head into pressure head.

Volute pumps have no diffusion vanes, but have a casing of spiral form, which gradually reduces the velocity of the water as it leaves the impeller, thus serving the same purpose as diffusion vanes in turbine pumps.

The turbine pump is adapted to and used for heads greater than 150 ft. A head of 100 ft. per stage is figured for most satisfactory results with this type of pump, although it is possible to operate against heads as high as 300 ft. per stage by operating pump at a high rate of speed. This, however, is not recommended as good practice.

The volute pump is a low head pump and is adapted to all classes of pumping service for which centrifugal pumps are used. Where the total head is not in excess of 150 ft. it is quite as efficient as the turbine type for low heads and has the advantage over the turbine type, that there are no diffusion vanes to become clogged up or require renewal.

Single and Double Suction Pumps

A further classification of centrifugal pumps may be made by dividing them into single and double suction pumps, depending on whether the water enters the impeller from one or both sides. Theoretically, the impeller in a double suction pump is balanced by reason of the water entering from both sides of the impeller, but it has been found in practice that this is not always true owing to variation in moving parts, and other conditions, and it is always advisable to have a thrust bearing.

With the single suction pump there is, of course, always an unbalanced condition of the impeller creating an end thrust which should be taken care of by thrust bearings.

Advantages of Centrifugal Pumps

1. Economy as to initial cost.
2. Low cost of maintenance.
3. The centrifugal pump runs with less noise than the average pumping equipment.
4. Centrifugal pumps may be operated successfully with inexperienced labor.
5. Failure to open a valve or the sudden closure of valves on the discharge will not effect the pump.
6. Less floor space is required than for other types of pumps of same capacity.
7. Is particularly adapted for handling muddy or sandy water with the least injury to working parts.
8. Starting valves, relief valves and air chambers on discharge line or vacuum chamber on suction line are unnecessary.
9. Can be used in series more satisfactorily than any other type of pump.
10. Pump is non-pulsating and does not cause water hammer on line.
11. Is particularly adapted where motor is used as power and automatic operation is desired.

Disadvantages of Centrifugal Pumps

1. The necessity for priming.
2. Will not operate if a slight amount of air leaks into the suction line.
3. Other types of pumps are capable of handling higher suction lifts more successfully.
4. Will not operate efficiently where there is a constant variation in the pumping head.

Proper Size and Stage of Pump to Be Used

In order to determine the above, the following information must be obtained:

- Gallons per minute required.
- Static discharge head.
- Suction head.
- Length and diameter of suction line.
- Length and diameter of discharge line.
- Number of elbows and bends in both suction and discharge lines.
- Nature of fluid to be pumped, whether clear or containing much sediment and grit.
- Class of power.

From the above can be determined the total net head under which the pump is to operate and this in turn will determine the size of pump and the number of stages for the unit in question.

The number of stages to be used in a pump size to perform a given amount of work under ordinary circumstances will depend on the total net head under which the pump is to operate, the amount of water to be delivered in gallons per minute, the diameter of the impeller and the speed at which the pump can be operated, based on the power to be used. As a general rule, it is safe to say that with heads ranging from 10 ft. to 100 ft. we can select a single stage pump; for heads ranging from 100 ft. to 200 ft., a 2-stage pump and for heads ranging from 300 ft. to 550 ft., 3 or more stages will be necessary, depending on the size and speed of the pump.

Power to Be Used

The power to be used may be:

1. Electric motor.
2. Internal combustion engine.
3. Steam turbine.
4. Steam engine.

An electric motor may be either direct connected to pump or belt drive used. A centrifugal pump direct connected to an electric motor makes an excellent pumping unit and will meet practically all pumping requirements owing to the fact that motors of practically any speed can be secured. A flexible coupling should be used in direct connecting a centrifugal pump to an electric motor. The belt drive is better suited to small centrifugal pumps than to large units.

Centrifugal pumps may be operated by squirrel cage motors instead of slip ring motors as the starting torque is not great. This shows a saving in the cost of power unit as the squirrel cage motor is not as expensive, nor as heavy as a slip ring motor.

The advantage of direct connected motor driven centrifugal pumps is in the saving in floor space and power transmission losses. High-speed motors are cheaper than low-speed motors and as the centrifugal pump is a relatively high speed machine there is consequent saving in total first cost.

Internal Combustion Engines direct connected or with belt drive are particularly adapted to operating centrifugal pumps, especially for railway water service. Considering power costs alone it is undoubtedly the most economical power that can be used, except where cost of attendance may be eliminated through automatic electric drive.

The **Steam Turbine** has proven a satisfactory method of operating centrifugal pumps in some cases but there are but few points where it could be used in railway water service. By an adjustment of the governor, the speed of the turbine can be readily altered to suit the varied demands made upon the pump. The steam turbine is efficient under partial loads.

The use of the **steam engine** for driving centrifugal pumps used in railway water service is limited and could be operated economically only where the exhaust steam was required for other purposes or perhaps where steam was available without the necessity for constructing a boiler plant.

Efficient Methods of Installation

To obtain efficient operation a special study must be made of each particular installation. Conditions under which pumping units operate vary to considerable extent and no set rules may be laid down to fit all conditions. The following suggestions are offered as applicable to general conditions covering centrifugal installations.

A certified characteristic curve of the pump at the speed recommended by the manufacturers should be furnished and studied carefully, special attention being given the following points:

(1) The unloading or non-overload feature in which the power is not increased materially should the head be reduced.

(2) The efficiency at various heads.

The horizontal, split casing type with enclosed impeller is recommended where conditions are adapted to its use as it presents the most accessible form of construction for inspection and repairs.

The bearings should be of the ring oiling type and provided with drip pockets connected to a drain to carry away the slight leakage that should be permitted through the stuffing boxes and glands.

A flexible coupling should be used on all direct connected units to connect the pump with the prime mover as this type of coupling permits for slight inaccuracies in the alinement of the shafts and insures cool bearings.

A check and gate valve should be placed on the discharge line near the pump. The check valve is to protect the pump from water hammer; the gate valve to regulate the discharge of the pump and to permit its removal without emptying the discharge line.

If a centrifugal pump is required to draw water from a single driven well, the suction pipe should be dropped down inside the well casing and the top of the casing should not be closed but left open, so that the air can have free access to the surface of the water.

The pump should be placed as near to the source of supply as possible, especially when operating with a suction lift.

In order to keep the suction line full of water, a foot valve should always be installed on the end of the suction pipe.

General Practice

The general practice is best represented by use of belt driven pumps with internal combustion engine using oil for fuel. Depending upon the cost of fuel as compared to cost of power, the internal combustion fuel oil engine or electric motor is preferable as power unit. Transmission other than belting has not been generally used by Railways. Silent chain drive appears to have an advantage in compactness of units and low transmission losses, but is largely offset by excessive first cost for the smaller installations. The use of indirect connected centrifugal pump usually arises from the necessity of putting the pump within reasonable suction lift of supply and keeping the prime mover, particularly, electric motors above possible extreme floods.

Appendix G

STANDARDS

C. R. Knowles, *Chairman;* R. C. Bardwell, *Sub-Committee.*

During the past year the Committee has given careful consideration to the adoption of standard specifications covering cast iron water pipe and special castings, and standard specifications for hydrants and valves. The conclusion reached was that the standard specifications of the American Water Works Association were complete in every detail and so well established that practically all cast iron pipe specials, valves and hydrants now used by railroads were furnished under these specifications. Therefore, upon the recommendation of the Standardization Committee, the Board of Direction instructed the Committee to present these specifications to the Association for approval.

Tables of sizes, classification, and illustrations may be obtained in pamphlet form from the Secretary of the American Water Works Association, 153 West 71st Street, New York City.

The specifications follow:

STANDARDS FOR CAST IRON WATER PIPE

(Adopted by the American Water Works Association May 12, 1908. Reprinted by permission.)

STANDARDS FOR HYDRANTS AND VALVES

(Adopted by the American Water Works Association June 24, 1912. Revised June 9, 1916. Reprinted by permission.)

STANDARD SPECIFICATIONS FOR CAST IRON PIPE AND SPECIAL CASTINGS

Description of Pipes.

Section 1. The pipes shall be made with hub and spigot joints and shall accurately conform to the dimensions given in Tables Nos. 1 and 2. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 ft. in length, exclusive of socket.

Pipes with thickness and weight intermediate between the classes in Table No. 2 shall be made of the same outside diameter as the next heavier class. Pipes with thickness and weight less than shown by Table No. 2 shall be made of the same outside diameter as the Class A pipe; and pipes with thickness and weight more than shown by Table No. 2 shall be made of the same outside diameter as the Class D pipe.

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 inches from each of the pipe so as to obtain the required standard thickness and weight for each size and class of pipe.

For pipes of each size from 4-inch to 24-inch inclusive, there shall be two standards of outside diameter, and for pipes from 30-inch to 60-inch inclusive, there shall be four standards of outside diameter, as shown by Table No. 1.

For pipes 4-inch to 12-inch inclusive, one class of special castings shall be furnished, made from Class D pattern. Those having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table No. 1, and shall be tapered back for a distance of 6 inches.

For pipes from 14-inch to 24-inch inclusive, two classes of special castings shall be furnished; Class B special castings with Classes A and B pipe, and Class D special castings with Classes C and D pipes; the former shall have cast on them the letters "AB" and the latter "CD." For pipes 30-inch to 60-inch inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall have cast on them the letter of the class to which they belong.

Allowable Variation in Diameter of Pipes and Sockets.

Section 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gauges, and no pipe will be received which is defective in joint-room from any cause. The diameters of the sockets and the outside diameters of the spigot ends of the pipes shall not vary from the standard dimensions by more than .06 of an inch for pipes 16 inches or less in diameter; .08 of an inch for 18-inch, 20-inch and 24-inch pipes; .10 of an inch for 30-inch, 36-inch and 42-inch pipes; .12 of an inch for 48-inch, and .15 of an inch for 54-inch and 60-inch pipes.

Allowable Variation in Thickness.

Section 3. For pipes whose standard thickness is less than 1 inch, the thickness of metal in the body of the pipe shall not be more than .08 of an inch less than the standard thickness, and for pipes whose standard thickness is 1 inch or more, the variation shall not exceed .10 of an inch, except that for spaces not exceeding 8 inches in length in any direction, variations from the standard thickness of .02 of an inch in excess of the allowance above given shall be permitted. For special castings of standard patterns a variation of 50 per cent greater than allowed for straight pipes shall be permitted.

Defective Spigots May Be Cut.

Section 4. Defective spigot ends on pipes 12 inches or more in diameter may be cut off in a lathe and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 feet in length, exclusive of the socket.

In case the length of a pipe differs from 12 feet, the standard weight of the pipe given in Table No. 2 shall be modified in accordance therewith.

Special Castings.

Section 5. All special castings shall be made in accordance with the cuts and the dimensions given in the tables forming a part of these specifications.

The diameters of the sockets and the external diameters of the spigot ends of the special castings shall not vary from the standard dimensions by more than .12 of an inch for castings 16 inches or less in diameter; .15 of an inch for 18-inch, 20-inch and 24-inch; .20 of an inch for 30-inch, 36-inch and 42-inch and .24 of an inch for 48-inch, 54-inch and 60-inch. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal heads and nuts and sound, well-fitting threads.

Marking.

Section 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe larger than 4-inch may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

1908	1908	1908
1	2	3

etc., also any initials, not exceeding four, which may be required by the purchaser. The letters and figures shall be cast on the outside and shall not be less than 2 inches in length and ⅛ of an inch in relief for pipes 8 inches in diameter and larger. For smaller sizes of pipes the letters may be 1 inch in length. The weight and the class letter shall be conspicuously painted in white in the inside of each pipe and special casting after the coating has become hard.

Allowable Percentage of Variation in Weight.

Section 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes, 16 inches or less in diameter, and 4 per cent for pipes more than 16 inches in diameter, and no excess above the standard weight of more than the given percentage for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 inches or less in diameter, and 8 per cent for larger sizes, except that curves, Y-pieces and breeches pipe may be 12 per cent below the standard weight, and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

Quality of Iron.

Section 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the three bars differ from those given below, a proper allowance therefor shall be made in the results of the tests.

Tests of Material.

Section 9. Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and in default of definite instructions the contractor shall make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 inches apart, and loaded in the center, shall support a load of 2,000 lb. and show a deflection of not less than .30 of an inch before breaking; or, if preferred, tensile bars shall be made which will show a breaking point of not less than 20,000 lb. per square inch.

Casting of Pipe.

Section 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 inches or less in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

Quality of Castings.

Section 11. The pipes and special castings shall be smooth, free from scales, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

Cleaning and Inspection.

Section 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

Coating.

Section 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300 degrees Fahrenheit immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300 degrees Fahrenheit (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated the pipe shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

Hydrostatic Test.

Section 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure, and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipe shall be subjected are as follows:

	20-inch Diameter and Larger Pounds per Square Inch	Less than 20-inch Diameter Pounds per Square Inch
Class A pipe	150	300
Class B pipe	200	300
Class C pipe	250	300
Class D pipe	300	300

Weighing.

Section 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer, the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made upon the basis of a ton of 2,000 lb.

Contractor to Furnish Men and Material.

Section 16. The contractor shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipe and special castings; and should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the tests upon the test bars.

Power of Engineer to Inspect.

Section 17. The engineer shall be at liberty at all times to inspect the material at the foundry, and the moldings, castings and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipe or other casting which is not in conformity with the specifications or drawings.

Inspector to Report.

Section 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

Castings to Be Delivered Sound and Perfect.

Section 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipes or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered until the final completion and adjustment of the contract; provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation at or any time after they have received the coating.

Definition of the Word "Engineer."

Section 20. Wherever the word "engineer" is used herein it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

STANDARD SPECIFICATIONS FOR HYDRANTS AND VALVES

Specifications for Hydrants

1. Size

Classification.—The size of hydrant shall be designated by the nominal diameter of the valve opening, which must be at least 4 inches for hydrants having two 2½ inch hose nozzles; 5 inches for hydrants having three 2½-inch nozzles; and 6 inches for hydrants having four 2½-inch nozzles; and shall be classed as one-way, two-way, three-way or four-way, etc., according to the number of 2½-inch hose outlets for which they are designed.

Area of Water Way.—The net area of the hydrant at the smallest part, when the valve is wide open, must not be less than 120 per cent. that of the valve opening.

Bell Ends or Flange Ends.—All hydrants must be fitted with bell ends to fit standard cast-iron pipe, or if flanged they must be fitted with flanges of the standard dimensions corresponding to the pressure under which they are to be used; connecting pipe or flange from main to hydrant in no case to be less in diameter than the valve opening. (The standards referred to are those adopted or that may be adopted by this Association.)

2. General Design

Type.—Hydrants may be of compression or gate type.

Change in Diameter.—Any change in diameter of the water passage through the hydrant must have easy curve, and all outlets must have rounded corners of good radius.

Water Hammer.—Hydrants must be so designed, particularly as regards the pitch of the thread of the operating stem, that, when properly operated a water hammer will not be caused which will give an increased pressure to exceed the working pressure, when such pressure is over 60 lb., nor increase the pressure more than 60 lbs. when operated under less working pressure than 60 lb.

Broken Hydrant.—Valve when shut must remain reasonably tight when upper portion of barrel is broken off.

Friction Loss.—With a 5-foot hydrant discharging 260 gallons per minute, through each 2½-inch outlet, the total friction loss of the hydrant must not exceed 2 lb. for two-way, 3 lb. for three-way, and 4 lb. for four-way hydrants.

Strapping.—When requested, hydrants must be fitted with 2 lugs, so that the leaded joint underground can be strapped.

Flange Joints Above Ground.—When hydrant barrel is made in two sections, the upper flange connection must be at least 2 inches above the ground line.

3. Material

Hydrant Body.—The hydrant body must be made of cast iron.

Cast Iron.—All castings shall be made from a superior quality of iron, remelted in cupola or air furnace, though and even grain, and shall possess a tensile strength of 22,000 lb. per sq. in. The casting must be clean and perfect, without blow or sand holes, or defects of any kind. No plugging or stopping of holes will be allowed.

Specimen Bars.—Specimen bars of the metal used, each being 26 inches long, by 2 inches wide, and 1 inch thick, shall be made without charge, as often as the engineer may direct, and in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 inches apart, and loaded in the center, shall support a load of 2,200 lb., and show a deflection of not less than 0.35 of an inch, before breaking; or, if preferred, tensile bars shall be made which shall show a breaking point of not less than 22,000 lb. per sq. in. Bars must be cast as nearly as possible to the dimensions without finishing, but corrections may be made by the engineer for variations in width and thickness, and the corrected result must conform to the above requirements.

Wrought Iron.—All wrought iron shall be of the best quality of refined iron of a tensile strength of at least 45,000 lb. per sq. in.

Composition Metals.—All composition or other non-corrodible metals used to be of the best quality, to have a tensile strength of not less than 32,000 lb. per sq. in., with a 5 per cent reduction of area at breaking point.

4. Hose Nipples and Valves

Hose Nipples.—Hose nipples must be of bronze or suitable non-corrodible metal, either threaded with a fine thread into the hydrants and securely pinned in place, or carefully locked and caulked in place.

Hose Threads.—Hose threads on all hydrants to be installed in any given community must of necessity be interchangeable with those already in service, but, where practicable threads should conform to the National Standard.

5. Hydrant Seat and Gate

Seat.—The seat must be made of bronze or suitable non-corrodible metal, securely fastened in place.

Valve.—The valve must be faced with a yielding material, such as rubber or leather, except that, if of the gate type, a bronze ring may be used. The valve must be designed so that it can be easily removed for repairs without digging up the hydrant.

6. Drip Valve

Drip.—A positively operating non-corrodible drip valve must be provided and arranged so as to properly drain the hydrant when the main valve is closed. The seat for the waste valve, which must be fastened in the hydrant securely, must be made of non-corrodible material. All other parts of the drip mechanism must be so designed as to be easily removed without digging up the hydrant.

7. Operating Parts

Operating Threads.—The operating threads of the hydrant must be so arranged as to do away with the working of any iron or steel parts against iron or steel. Either the operating screw or the operating nut must be made of non-corrodible metal, and sufficiently strong to perform the work for which intended.

Top Nut.—The stem must terminate at the top in a nut of pentagonal shape, finished with slight taper to 1½-inch from point to flat, except for hydrants to be installed where existing hydrants have different shape or size of nut, in which case the additional hydrants must have operating nuts similar to the old one for uniformity. The nut socket in the wrench must be made without taper, so as to be reversible.

8. Stuffing Box and Gland

Stuffing Box.—The stuffing box and gland must be of bronze or suitable non-corrodible metal, or bushed with bronze or suitable non-corrodible metal, when an iron or steel stem is used, or when an iron operating stem nut passes through the stuffing box. When packing nut is used, it must be made of bronze or suitable non-corrodible metal. The bottom of the box and end of the gland or packing nut must be slightly beveled.

Gland Bolts.—Gland bolts or stubs must be at least ½-inch in diameter. Bolts or studs may be either of bronze or suitable non-corrodible metal, iron or steel. The nuts must always be of bonze or suitable non-corrodible metal.

9. Hydrant Top

Top.—The hydrant top must be designed so as to make the hydrant as weather proof as possible, and thus overcome the danger from water getting in and freezing around the stem. Provisions must be made for oiling, both for lubrication and to prevent corrosion. A reasonably tight fit should be made around the stems.

Lettering.—There must be cast on top of the hydrant in characters raised ⅛-inch, an arrow at least 2½ inches long, and the word "open" in letters ½ inch high and ⅛ inch in relief, indicating direction to turn to open the hydrant.

10. Hose Cap

Caps.—Hose caps must be provided for all outlets, and must be securely chained to the barrel with a chain constructed of material not less than ⅛ inch in diameter.

Cap Nut.—The hose cap nut must be of the same size and shape as the top or operating nut.

Washer in Cap.—When requested by the purchaser, a leather, rubber or lead washer must be provided in the hose cap, set in a groove to prevent its falling out when the cap is removed.

11. Markings

Marking.—The hydrant must be marked with the name or particular mark of the manufacturer. All letters and figures must be cast on the hydrant barrel above the ground line.

12. Testing

Testing.—Hydrants for pressures of 150 lb. or less, after being assembled, shall be tested by hydraulic pressure to 300 lb. per sq. in., before leaving the factory. If the working pressure is over 150 lb. per sq. in. the hydrants must be tested to twice the working pressure. The test must be made with the valve open in order to test the whole barrel for porosity, and strength of hydrant body. A second test must be made with valve shut, in order to test the strength and tightness of the valve.

13. Directions to Open

Opening.—Hydrants must open to the left (counter clockwise) except those to be installed where existing hydrants open to the right, in which case the additional hydrants must turn the same as the old one for the sake of uniformity.

SPECIFICATIONS FOR VALVES

Castings

Castings.—All iron castings shall be made from a superior quality of iron, remelted in cupola or air furnace, tough and of even grain, and shall possess a tensile strength of 22,000 lb. per sq. in. The castings must be clean and perfect, without blow or sand holes or defects of any kind. No plugging or stopping of holes will be allowed.

Test Bars

Test Bars.—Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 inches apart, and loaded in the center, shall support a load of 2,200 lb., and show a deflection of not less than .35 of an inch before breaking; or, if preferred, tensile bars shall be made which will show a breaking point of not less than 22,000 lb. per sq. in. Bars to be cast as nearly as possible to the dimensions without finishing, but corrections may be made by the engineer for variations in width and thickness, and the corrected result must conform to above requirement.

Makers' Name

Name.—Each valve shall have the makers' name cast upon it.

Wrought Iron

Wrought Iron.—All wrought iron used shall be of the best quality of refined iron, of a tensile strength of at least 45,000 lb. per sq. in.

Composition Metals

Composition.—All composition metals to be of the best quality, and, except the stems, to have a tensile strength of not less than 30,000 lb. per sq. in., with 5 per cent elongation in 8 diameters, and 5 per cent reduction of area at breaking point.

Face Joints

Face Joints.—All joints shall be faced true and smooth, so as to make, with suitable gaskets, a perfectly watertight joint.

Fitting and Interchangeable Parts

Fittings.—The fitting of all parts must be such as make perfect joints and all parts of the valves of the same make and the same size shall be interchangeable.

Valves to open as specified by the engineer.

Bolts and Nuts

Bolts and Nuts.—All bolts and nuts in valves to be made from the best quality of double refined wrought iron or steel, heads, nuts and threads to be standard sizes.

Kind of Valves

Kind.—Valves shall be fully mounted with bronze or suitable noncorrodible metal, and be either of the double disc or made up gate type with bronze or suitable noncorrodible metal mounted wedging devices or have wedge-shaped gates with double faces and seats, designed to work equally well with pressure on either side of the gate. The gates (or discs) shall be of cast iron with bronze or suitable non-corrodible metal faces. These faces shall be machined, dovetailed and driven into corresponding machined grooves in gates (or discs) or riveted on with bronze or suitable noncorrodible metal rivets.

The seats for composition rings in body of valve shall be turned and threaded before rings are screwed in.

To Be Water Tight

Seat and Gate Rings.—Both seat rings and gate (or disc) rings shall have smooth and true faces, and make a perfectly watertight joint.

Valves shall have hub ends suitable for laying with classes B and C American Water Works Association standard pipe. All valves 24 inches in diameter and larger shall be geared.

Bypasses.—Where bypasses are required, they shall, unless otherwise specified, be of the following sizes:

16-inch valve	3-inch bypass
18-inch and 20-inch valves	3-inch bypass
24-inch and 30-inch valves	4-inch bypass
36-inch and 42-inch valves	6-inch bypass
48-inch valves	8-inch bypass

Weight.—Valves without bypasses shall be approximately not less than the following weights for the respective sizes:

3-inch	67 lb.
4-inch	85 lb.
6-inch	180 lb.
8-inch	255 lb.
10-inch	400 lb.
12-inch	500 lb.
14-inch	780 lb.
16-inch	900 lb.
18-inch	1,290 lb.
20-inch	1,700 lb.
24-inch, geared	2,750 lb.
30-inch, geared	5,200 lb.
36-inch, geared	8,500 lb.
42-inch, geared	12,000 lb.
48-inch, geared	18,000 lb.

Valve Stems

Stems.—Valve stems shall be made of solid brass or suitable non-corrodible metal, free from defects, and shall have a tensile strength of not less than 45,000 lb. per sq. in.

Threads.—Threads on stems to be square, acme or ½ V, and cut in most perfect manner, so as to work true and smooth and in perfect line throughout the lift of the valve.

Size of Stems.—Valve stems at the bottom or base of the thread shall not be less than the following sizes in diameter:

3-inch valve	44/64 inch
4-inch valve	55/64 inch
5-inch valve	55/64 inch
6-inch valve	1 inch
7-inch valve	1 inch
8-inch valve	1 inch
9-inch valve	1 8/64 inch
10-inch valve	1 8/64 inch
12-inch valve	1 12/64 inch
14-inch valve	1 12/64 inch
16-inch valve	1 28/64 inch
18-inch valve	1 28/64 inch
20-inch valve	1 48/64 inch
22-inch valve	1 48/64 inch
24-inch valve	1 62/64 inch
30-inch valve	2 12/64 inch
36-inch valve	2 32/64 inch
42-inch valve	2 48/64 inch
48-inch valve	3 32/64 inch

Wrench Nut.—The wrench nut on stem shall be inches square with arrow cast on showing direction which valve is to turn to open.

Painting

Painting.—All iron work, after being thoroughly cleaned, to be painted throughout with asphaltum varnish, or suitable paint, or dipped in suitable coating material.

Testing

Testing.—Valves must be tested for leakage and distortion as follows: On double disc or made up gate type, the body of the valve shall be drilled and tapped with a hole for pipe and a removable plug inserted, through this hole a hydraulic pressure of 300 lb. per sq. in. shall be applied; the wedge-shaped gate type by an hydraulic pressure of 300 lb. per sq. in. applied, first between one end and the gate, second between the opposit end and the gate, and third in the bonnet with gate open.

Appendix H

UNIVERSITY WORK OF INTEREST TO RAILWAY WATER SUPPLY

R. C. BARDWELL, *Chairman;* C. R. KNOWLES, *Sub-Committee.*

Communication from Prof. G. A. Young, head of Mechanical Engineering at Purdue University, to the President of this Association relative to work of interest on water treatment in progress at the university, was forwarded to this Committee for establishing contact and report.

Investigation developed that during the school year 1920-1921, study on this subject was started under the direction of H. Ruebenkoeing, Professor of Railway Mechanical Engineering. To date a large bibliography on water treatment has been collected and abstract prepared. Further work and study is contemplated when facilities become available.

Work of further interest in connection with water treatment under varying heat conditions is being conducted under the direction of Dr. Edward Bartow, head of the Chemistry Department, University of Iowa, Iowa City, Iowa. Considerable data has been secured, but the results are not as yet ready for publication.

During the year 1919-1920, investigation of interest in connection with study of the electrolytic phase of pitting and corrosion was carried on by D. A. Steel at the University of Montana, Bozeman, Montana. The work indicated that the injurious effects caused by the presence of varying amounts of the common electrolytes, sodium sulphate and sodium chloride, can be inhibited by the presence of definite proportions of various hydrates and alkaline salts. The results secured are not sufficiently definite for authoritative publication, and it is suggested that further investigation be carried out along these lines.

Recent work of interest on the subject of "The Self-Corrosion of Cast-Iron and Other Metals in Alkali Soils" was carried out by W. Nelson Smith and Dr. J. W. Shipley at the University of Manitoba, Winnipeg, Canada, results of which have been published in the October, 1921, issue of the Journal of the Engineering Institute of Canada.

Advice has been received that study and investigation is contemplated at the Chemical Laboratory of the Sheffield Scientific School, Yale University, under the direction of W. T. Read, who was author of the University of Texas Bulletin 1752, published under date of September 15, 1917, on "Boiler Waters, Their Chemical Composition, Use and Treatment," which has been a valuable addition to the compilation of information on this subject. Revision of the work covered by this bulletin with inclusion of further information is a possibility.

This Committee fully realizes the importance of research work as carried out by the various universities throughout the country and appreciates the value of such work to the railroads. The facilities available at our universities for carrying on this work together with the scientific personnel in charge, give assurance of development of ideas and conclusions of practical value. With the approval of the Association your Committee will be pleased to keep in touch with this matter and report developments from time to time.

REPORT OF COMMITTEE XX—UNIFORM GENERAL CONTRACT FORMS

W. D. Faucette, *Chairman;*
C. A. Wilson, *Vice-Chairman;*
C. F. Allen,
Frank Taylor,
J. C. Irwin,
A. C. Shields,
C. B. Niehaus,
J. B. Carothers,
O. K. Morgan,
W. H. Brameld,
H. A. Palmer,
W. A. Duff,
C. J. Parker,
F. H. Fechtig,
E. L. Taylor,
Clark Dillenbeck,

Committee.

To the American Railway Engineering Association:

Your Committee on Uniform General Contract Forms respectfully submits the following report:

(1) Revision of Manual

In Appendix A, covering Revision of the Manual, certain changes have been recommended for adoption by the Association. This work was in charge of a Sub-Committee, Chairman of which was Clark Dillenbeck, the members of his Sub-Committee being: Clark Dillenbeck, J. C. Irwin, C. B. Niehaus, E. L. Taylor and Frank Taylor. The conclusions and recommendations of this Sub-Committee are referred to hereinafter.

(2) Report of Certain Forms of Agreement

To a Sub-Committee composed of J. C. Irwin as Chairman, with the following members: J. C. Irwin, C. A. Wilson, E. L. Taylor, H. A. Palmer, C. F. Allen and F. H. Fechtig, was assigned (1) the submission of a final report on agreement covering the construction of "Electric Conductor, Conduits, Pipe Lines and Drains on Railroad Property," and (2) agreement for "Trackage Rights" In Appendix B is submitted the report of this Sub-Committee and at the close of the Sub-Committee's report is the final draft of a "Form of License for Wires, Pipes, Conduits and Drains on Railroad Property," which is recommended for approval and insertion in the Manual.

(3) Report on Agreement for Private Road Crossing and for Purchase of Electricity

The work referred to in the caption was assigned to a Sub-Committee, of which E. L. Taylor was Chairman, with the following members: E. L. Taylor, C. B. Niehaus, J. B. Carothers, W. A. Duffy, H. A. Palmer and W. H. Brameld. This Committee has given considerable thought and study to the subjects assigned and its report is submitted in full in Appendix C.

The Sub-Committee was able to submit a carefully worked out progress report on "Form of License for Private Road Crossing." This form of license, which is printed in full as a progress report, includes therein several paragraphs which the Sub-Committee felt it proper to include. No Liability Clause is inserted, but a blank number is left therefor and by the next Convention it is expected that this clause will be in shape for final submission. It developed that there was considerable differences of opinion in the Sub-Committee and also in the General Committee with respect to this Liability Clause and it was considered best not to attempt to print in this progress report the several Liability Clauses which had been submitted. It is the wish of this Committee to receive any criticism or suggestion in connection with this Form or the Liability Clause and it is hoped that this same subject will be reassigned this Committee as a part of next year's work.

(4) Form of License for Wires, Pipes, Conduits and Drains on Railroad Property

The Committee makes its final report on "Form of License for Wires, Pipes, Conduits and Drains on Railroad Property," and recommends to the Association the adoption of this form of Agreement.

Your Committee realizes that in presenting a draft of proposed Agreement or License of this character that it is hardly possible that such an Agreement can be adopted by any one railway without some modifications to fit the conditions local to the individual railway. It is hoped, however, that this Form of Agreement will, if adopted by the Association, be a guide in the drafting of such forms in the future. In all of these Agreements the Committee has endeavored to make them simple, clear and easily understood, with the hope that no unnecessary and irrelevant material will be inserted therein.

It is the experience of your Committee that legal departments of the different railways desire very often to recast these agreements in a language approved by each individual law department. Your Committee does not feel that the phrasing of these agreements is the best that could be done, but it is the hope that if it is adopted by the Association that it will be used in as near the form presented as may be possible.

Work of Committee XX

During the year this Committee received with regret the resignation of Mr. C. J. Parker of the New York Central Lines. It was not thought necessary to appoint any other member in place of Mr. Parker for the remainder of the year.

In December the Chairman of your Committee was designated by President Downs of the American Railway Engineering Association to attend a conference in Washington, called by the Associated General Contractors of America, to represent the American Railway Engineering Association at that conference. The meeting was held in the office of Secretary of Commerce Hoover and was opened by the Secretary. His remarks being of such import we feel it desirable to quote them, as follows:

"Well, gentlemen, this conference is to consider whether something can be done to standardize or simplify or reinforce or generally improve the whole basis of contract forms used in the construction industry. I believe there is a great field there not only in protection to the public, but in the general improvement of the ethics of the industry itself. I don't profess to know much about it, but it is a matter that has not come under my purview for some years. I have been too much out of the engineering work for the last seven years to give much thought to it.

"I know that the time I was in engineering work this whole variation and specification of the contract basis for construction work of all kinds was an outstanding sore, and I have been in hopes that it was possible to do something. It all comes in line with the things many of us are concerned with, and that is fundamentally the elimination of waste, lost motion, improvement of business practice throughout the whole of the United States, and we have to remember that we have now an enlarged and inflated cost of distribution primarily rather than production, and that we have a disparity due to the fundamentals of the increase in Federal taxation and railway rates that are making a wider margin between production and final distribution costs than we have ever had to face before, and unless we can crowd that margin down somewhat by just share increase in efficiency we are not going to be able to hold up our competitive position outside. So this is one of those things that ramify in many directions.

"I now, therefore, leave it to you, and we are glad to have you come to this Department, because we have started a definite program along all these lines, not from a point of view of trying to compel anybody to do anything, but trying to mobilize all the different branches of industry for co-operative action, and while you can do much to get this thing straightened out it is probable that the Department of Commerce could be of moral assistance to you in getting it over when you have once arrived at some conclusions, and we will be delighted to back up anything that you come to an agreement on, and I have been astonished at the desire of the different industries to effect these things in every direction and their willingness to co-operate with other industries to make the work of each individual industry effective.

"We had the case the other day of the simplification of certain manufactured articles. The great majority of the manufacturers were represented here, but claimed that some minority would not help. They could not do anything without the assistance of other branches, and therefore I called in both the wholesalers and retailers in those directions and asked them if they would co-operate, and they have co-operated so far as to almost set up a boycott against certain manufacturers because they would not fall into line with the great majority, and they did it purely out of national interest.

"Somebody somewhere has got to eliminate the waste in this whole situation. I only mention that as a point where this Department can be of help in getting the allegiance of the related industries and trades, and help you to get over some program of this kind.

"So that is all I am doing, is to give you our blessing and to tell you that the Department of Commerce is yours. Go to it.

"Now it is up to you, I think."

* * * *

Without going into the details of the two days' session, the general idea was to formulate, if possible, a standard national construction contract, that could be used or adopted in all the different branches of the construction industry, and have the contract of such flexibility to make it possible of adaptation to any of the general branches of construction. This would, of course, eliminate those conditions from such a standard document as would be entirely local or applicable to special kinds of work; such special paragraphs or conditions would have to appear in the document when drafted for any special work.

The two days were spent in coming to an understanding as to the method of procedure and a starting point for the formulation of such a standard national construction contract. The names of such paragraphs as might be inserted in such a national document were named and agreed upon. No wording or phraseology for any of these named paragraphs were written. The full typewritten report of 374 pages has been submitted to the President and Secretary of the Association.

There were present as delegates to this conference the following:

Wm. Stanley Parker, representing American Institute of Architects.

H. K. Bishop, representing American Association of State Highway Officials.

L. W. Wallace, alternate for Col. C. O. Sherrill, representing American Engineering Council.

J. S. Langthorn, alternate for H. Eltinge Breed, representing American Society of Civil Engineers.

G. Waldo Smith and John M. Goddell, representing American Water Works Association.

J. W. Cowper, General R. C. Marshall and Ward P. Christie (Secretary of the meeting), representing Associated General Contractors of America.

E. W. Reaugh, representing National Association of Builders' Exchanges.

W. A. Rogers, alternate for Onward Bates, representing Western Society of Engineers.

Wm. B. King, representing American Bar Association.

W. D. Faucette, representing American Railway Engineering Association.

And at the close of the conference the following resolutions were adopted:

"Whereas, the preliminary conference of representatives of architectural, engineering and contracting organizations in Washington on December 15th and 16th has resulted in the development of certain views regarding the arrangement and wording of clauses in forms of contract documents for the further consideration of the delegates to the conference, and

Whereas, the American Institute of Architects and the American Railway Engineering Association have already adopted standard documents of this character, therefore

Be it Resolved by the delegates assembled at the preliminary conference, that General R. C. Marshall, Jr., is requested to prepare, in consultation with the delegate of the American Institute of Architects and the American Railway Engineering Association, a document embodying these opinions for the further consideration of the delegates, to be accompanied if practicable by a statement of the items in which the new document departs from the standard documents of the American Institute of Architects and the American Railway Engineering Association, and such other information and such suggestions as these gentlemen may deem it desirable to place before the delegates."

A full report has been made to President Downs and instructions are awaited prior to the next meeting of the delegates.

CONCLUSIONS

(1) The Committee recommends the changes in the Manual as set forth in Appendix A be adopted and that the Committee on Roadway be requested to make the revisions referred to in Appendix A.

(2) The Committee recommends "Form of License for Wires, Pipes, Conduits and Drains on Railroad Property," set forth and printed in Appendix B be adopted and printed in the Manual.

(3) The Committee recommends that the report of Sub-Committee referred to in Appendix C be received as information, with the request that any criticism and suggestions be given this Committee in order that a final report may be made next year on "Form of License for Private Road Crossings."

Recommendations for Future Work

Your Committee recommends that the following list be considered in making future assignments of work to this Committee:

(1) Make a thorough examination of subject matter in the Manual, submitting definite recommendations for changes.

(2) That the Form of License for Private Road Crossings, which was submitted this year for information, be reassigned this Committee for further study.

(3) That the Committee submit a Form of Agreement for:

(a) Trackage rights;
(b) Joint use of passenger station;
(c) Joint use of freight facilities;
(d) Purchase of electricity (which it is expected this Committee will finish next year), and
(e) Certificate of work by Chief Engineer.

Next attached, in order, are Appendices, A, B and C referred to in the early part of this report.

It will be the purpose of this Committee to use the word "Railway Company" hereafter instead of "Railroad Company." This is adopted for the sake of uniformity.

Before closing out the report of the year, the Committee records with pleasure the satisfactory attendance at the different meetings and the interest manifested by its membership.

Respectfully submitted,

THE COMMITTEE ON UNIFORM GENERAL CONTRACT FORMS,

W. D. FAUCETTE, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

Clark Dillenbeck, *Chairman, Sub-Committee.*

Proposed Revisions to the Manual—"Form of Construction Contract," Section 38, "Final Estimates," page 665:

(1) It is *recommended* that the word "whole" be omitted from the second line, as indicated below:

Present Form	*Proposed Form*
Upon the completion and acceptance of the work, the Chief Engineer shall execute a certificate over his signature that the *whole* work provided for in this agreement has been completed and accepted by him under the terms and conditions thereof, whereupon the entire balance found to be due to the Contractor, including said retained percentage, shall be paid to the Contractor at the office of the Treasurer of the Company within .... days after the date of said final certificate.	Upon the completion and acceptance of the work, the Chief Engineer shall execute a certificate over his signature that the work provided for in this agreement has been completed and accepted by him under the terms and conditions thereof, whereupon the entire balance found to be due to the Contractor, including said retained percentage, shall be paid to the Contractor at the office of the Treasurer of the Company within .... days after the date of said final certificate.

It was called to our attention that the American Railway Development Association had some observations to make on "Form of Industry Track Agreement" and "Form of Lease Agreement for Industrial Site" and we were instructed to get in communication with George E. Bates, their President, which resulted in Mr. Bates appointing a special committee to meet jointly with our Sub-Committee No. 2 to carefully consider these Forms of Agreements.

We have held two joint meetings, and although we are making good progress, the threatened Railroad Strike prevented several members of the American Development Association from attending our second meeting, rendering it impossible to conclude our work in time for our Committee to make any recommendations for revisions to these forms in the Manual this year.

(2) As regards the use of the word "railway" and the word "railroad" in the Manual, for uniformity it is *recommended* that hereafter the word *"Railway"* shall be used in all forms and specifications, and when the Manual is reprinted wherever the word "railroad" occurs it shall be changed to *"Railway."*

(3) "Specifications in the Manual in connection with which any uniform general contract form would or should be used."

It is found that the Specifications for Roadway were compiled before the organization of the Committee on General Contract Forms, and included therein General Conditions for the construction of such roadway and stated in these Conditions that the Specifications and General Conditions formed the entire Agreement. Our "Form of Construction Contract" has since been adopted and printed in the Manual, and now when a complete contract is attempted by the use of the Form of Construction Contract and the Specifications for Roadway, as printed in the Manual, the contract will contain some terms which are contradictory and some that result in ambiguity.

Your Committee recommends that the report covering study of all specifications in the Manual in connection with which any Uniform General Contract Form would or should be used, be accepted and the Committee on Roadway and the Committee on Uniform General Contract Forms be requested to revise the Specifications for Roadway so that the "General Conditions" of the Specifications as now printed in the Manual be omitted from the Specifications and covered by the General Conditions of the Construction Contract Form.

Appendix B

FORM OF LICENSE FOR WIRES, PIPES, CONDUITS AND DRAINS ON RAILWAY PROPERTY

J. C. Irwin, *Chairman, Sub-Committee.*

The work assigned to this Sub-Committee included:

1. The submission of a final report on agreement covering the construction of electrical conductors, conduits, pipe lines and drains on railroad property.
2. The collection of data for agreement for "Trackage Rights."

The Sub-Committee has completed its work on the first item and submits herewith attached the "Form of License for Wires, Pipes, Conduits and Drains on Railroad Property," as approved in the general meeting of Committee XX, December 9th, 1921, and recommends its adoption.

The Sub-Committee reports progress on the second item. It has collected thirty-four forms of Agreement for Trackage Rights used by representative railroads throughout the United States and Canada; has indexed and made synopses of these agreements and has commenced the writing of a proposed "Typical Form of Agreement for Trackage Rights," embodying the points that might be covered by the majority of such agreements but recognizing the fact that many of the points included in such agreements are local in character.

The Sub-Committee plans to continue this work without interruption, if it is again assigned.

FORM OF LICENSE FOR WIRES, PIPES, CONDUITS AND DRAINS ON RAILWAY PROPERTY

(Final form submitted for adoption)

THIS AGREEMENT, made this .... day of .... 19...... by and between the ...., hereinafter called the Railway Company, and ...., having a principal office or place of business in .... hereinafter called the Licensee, Witnesseth;

Whereas, the Licensee desires to construct, maintain and use ....
....
....
....
upon the property of the Railway Company, situated.................... ...., and substantially as shown on the plan hereto attached, designated as ...., dated ...., and made a part hereof:

It is mutually agreed as follows:

1. The Railway Company grants permission to the Licensee to construct, maintain and use ....
upon the property of the Railway Company, in accordance with said plan and the specifications forming a part hereof, and subject to the requirements of the Railway Company.

2. In consideration of this license, the Licensee shall pay to the Railway Company, in advance, the sum of ....
per .... beginning ....

3. Every cost and expense of construction, maintenance, use and removal resulting from this license, shall be paid by the Licensee. The Railway Company may perform, without notice, any work which it considers necessary to the safe operation of the railroad. The Licensee shall do no work under this license, which may interfere with the operation of the railroad without the written permission of the Railway Company.

4. Use of the property of the Railway Company, however long continued, shall not create any estate or easement in the Licensee or any rights other than license.

5. The Licensee shall idemnify, protect, and save harmless, the Railway Company from and against all claims, suits, costs, charges, and damages, made upon or incurred by the Railway Company in connection with this license.

6. This agreement may be terminated by either party by ....
.... notice to the other party, or without notice on disuse by the Licensee for ....

7. Any notice given by the Railway Company to the Licensee shall be deemed to be properly served if the notice be delivered to the Licensee, or if left with any responsible agent of the Licensee, or if mailed, post paid, addressed to the Licensee at the last known place of business of the Licensee.

8. Upon termination hereof the Licensee shall forthwith remove all the Licensee's constructions from the property of the Railway Company, to the satisfaction of the Railway Company. In case of the Licensee's failure so to do, the Railway Company may at its option either retain such construction or remove them at the cost of the Licensee.

9. This agreement shall not be assigned or in any manner transferred, without the written consent of the ....
of the Railway Company.

10. Until terminated as hereinbefore provided, this agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, the parties hereto have executed this agreement on the day and year first above written.

Witness....................................

....
Railway Company.

Witness....................................

....
Licensee.

By..

Appendix C

TENTATIVE FORM OF LICENSE FOR PRIVATE ROAD CROSSING

E. L. TAYLOR, *Chairman, Sub-Committee.*

The work assigned to Sub-Committee was:

(a) Submit form of agreement for private road crossing.

(b) Submit form of agreement for purchase of electricity.

1. It was understood that Sub-Committee would prepare a form of agreement for private road crossings which would be suitable for crossings over, under or at grade.

The Sub-Committee prepared such a form and it was submitted to the General Committee at its December meeting. The form recommended by the Sub-Committee was substantially satisfactory with a few minor changes but there was so much divergence of opinion on the liability clause that it was deemed best not to submit final form and to carry it over for further consideration next year. Progress report form submitted below.

2. Sub-Committee prepared tentative form of agreement for purchase of electricity but it was decided to hold it over until next year for submission to the Committee on Electricity, as their opinions and suggestions are desirable and necessary.

TENTATIVE FORM OF LICENSE FOR PRIVATE ROAD CROSSING

(Submitted as Progress Report)

The ...., hereinafter called the Railway Company, hereby gives to ...., hereinafter called the Licensee, the license and privilege of constructing, maintaining .... an overhead .... over .... and using a grade crossing over the lands and right-of-way and across the tracks........................... an undergrade .... under .... of the Railway Company situated .... and substantially as shown on the plan hereto attached, designated as.............................. .... and dated .... and made a part hereof:

1. The term of this License shall date form ....19......, and shall continue until terminated by a written notice given by either party to the other at least .... days prior to the date of termination.

2. The Licensee shall pay to the Railway Company as consideration for said license and privilege, the sum of .... on the ....day of every .... during the continuance of this license, and pro rata for a shorter period; a proportionate part of said consideration to be refunded to the Licensee in case of termination hereof by the Railway Company prior to the date to which the consideration shall have been paid.

3. The Licensee shall, at its own expense, construct and maintain said crossing in compliance with all statutory regulations and to the satisfaction of the Railway Company, and under the Railway Company's supervision and direction, and, except in case of emergency, shall do no work with reference to the maintenance of said crossing except under such supervision and direction, and after reasonable notice in writing to the Railway Company. The Railway Company may, at its option, construct and maintain said crossing and in such event, the Licensee shall pay to the Railway Company the entire cost and expense of all labor performed and materials furnished by the Railway Company in constructing and maintaining said crossing.

4. The Licensee shall provide and maintain such protection by signs or otherwise as the Railway Company may consider necessary.

5. The Licensee shall permit said crossing to be used only by the Licensee's agents and servants and by persons having business with the Licensee.

*6. Liability Clause.

7. The Licensee shall on request of the Railway Company remove said crossing from the premises of the Railway Company or make such changes in said crossing as may be required by the Railway Company, if such removal or changes shall in the judgment of the Railway Company be needed in connection with the development or use of the premises of the Railway Company. The Railway Company may, at its option, do such work and in such event, the Licensee shall pay to the Railway Company in connection with such work.

In Witness Whereof, the parties hereto have executed their agreement to this license, this .... day of .... 19.........

Witness....................................

....

Railway Company.

Witness....................................

....

Licensee.

By...

*Note—On account of different opinions in the Committee no tentative form of liability clause is submitted with this report. This will be submitted later.

REPORT OF COMMITTEE VIII—ON MASONRY

J. J. YATES, *Chairman;*
J. T. ANDREWS,
R. ARMOUR,
T. L. CONDRON,
W. A. CHRISTIAN,
J. E. FREEMAN,
T. L. D. HADWEN,
DR. W. K. HATT,
S. C. HOLLISTER.
RICHARD L. HUMPHREY,
NOAH JOHNSON,
JOB TUTHILL, *Vice-Chairman;*
S. A. JORDAN,
W. S. LACHER,
J. C. NAGLE,
C. P. RICHARDSON,
F. E. SCHALL,
Z. H. SIKES,
F. P. SISSON,
G. H. TINKER,
C. C. WESTFALL,
Committee.

To the American Railway Engineering Association:

The Committee presents reports on subjects 1, 3, 6 and 7.

Subject 2: On the subject of Design of Concrete and Reinforced Concrete Structures as developed by the Joint Committee on Concrete and Reinforced Concrete, no recommendations are made at this time.

The tentative report has been reviewed and certain suggestions made to the Joint Committee, but the Specification for Design is now in the discussion stages and it is possible changes may be made. In view of the condition the Committee does not think it advisable to make recommendations at this time.

Subject 4: A questionnaire was issued by the Sub-Committee, regarding failures of concrete structures, and many answers are being received which are being tabulated and a report will be issued next year.

Subject 5: There seems to be a lack of reliable information on this subject of the distribution of loads through ballast and embankment as affecting the design of masonry structures, and the Sub-Committee having this in charge is recommending that it be continued with the expectation that experimental data will become available the coming year.

Subject 6: A "Progress Report of the Joint Commiteee on Standard Specifications for Concrete and Reinforced Concrete" has been submitted in pamphlet form to the membership for discussion. (See Appendix E.)

CONCLUSIONS

Your Committee recommends the following action be taken on its report:

1. That the following requirement as it appears in the 1921 Manual, covering a variation in fineness of cement, be omitted and the remaining paragraphs renumbered. (See Appendix A.)

Permissible Variation.

36. A permissible variation of 1 will be allowed, and all results in excess of the specified limit, but within this permissible variation shall be reported as 22 per cent.

2. That the revisions and additions as they appear in Appendix A be issued as a supplement to the Specifications for Plain and Reinforced Concrete and for Steel Reinforcement as it appears in the Manual.

3. That Appendix B be received as information.

4. That Appendix C be received as information.

5. That the recommendations of the Committee as they appear in Appendix D be approved as the outline of work for the ensuing year.

Respectfully submitted,

The Committee on Masonry,

J. J. Yates, *Chairman.*

Appendix A

REVISION OF MANUAL

Since the adoption of a Specification and Tests for Portland Cement in 1917, the allowance of a variation of 1 per cent passing the No. 200 sieve, as provided in the Tests for the Determination of Fineness, has under an agreement by those interested been omitted from the specification.

The specification as amended has been approved on January 15, 1921, as "Tentative Standard" by the American Engineering Standards Committee.

The Committee is recommending that we omit paragraph 36 in order to make our specification identical.

The Progress Report of the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete was submitted to the constituent organizations June 4, 1921, and it has been issued to the members of the American Railway Engineering Association. Under the rules of organization of that committee the discussion of this report will be open for not less than six months nor more than one year from the above date.

A number of discussions have been received from members and your Committee has reviewed the specifications but will defer its report until some time after the Annual Convention, when it is hoped the discussions will all be in. It is then the intention of this Committee to again review the report and make recommendations for presentation to the Joint Committee.

In view of the advancement in the art that has been developed through the work of the Joint Committee, it is the recommendation of the Masonry Committee that certain changes and additions to the Specifications for Plain and Reinforced Concrete and for Steel Reinforcement, as they appear in the Manual, be issued as a supplement in order to keep our specifications up to date as follows:

For Paragraph 11, on Consistency, substitute the following:

11 (a) The quantity of water used in mixing shall be the least amount that will produce a plastic or workable mixture which can be properly compacted in the forms and around the reinforcement. Under no circumstances shall the consistency of the concrete be such as to permit a separation of the coarse aggregate from the mortar in handling.

(b) The Engineer shall determine and specify the consistency of the concrete for various portions of the work based on test of the materials to be used. The consistency of the concrete shall be measured by the slump test (for description of test and methods of making slump tests, see Vol. 22, Proceedings for 1921, pages 553 to 564 inclusive).

(c) The consistency of the concrete shall be checked at the beginning of each daily run, and at least once a day thereafter during the progress of the concreting, or when the size of any aggregate or its moisture condition changes.

Under the general heading of Materials, Paragraphs 1 to 7 inclusive, add the following paragraph:

Organic Impurities in Sand.—Natural sand which shows a color darker than the standard color when tested in accordance with the Colorimetric Test for Sands (see Appendix B) shall not be used unless the concrete made with the materials and in the proportions to be used on the work is shown by tests to be of the required strength.

As a footnote to the section on Steel Reinforcement, Paragraph 7, add the following:

See Appendix C for "Tentative Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement."

Include under section on Steel Reinforcement the following:

Standard Sizes of Bars. Reinforced bars shall conform to the areas and equivalent sizes shown in Table I.

Table I—Sizes and Areas of Reinforced Bars.

Size of Bar Inches	*Area, sq. in. Round*	*Area, sq. in. Square*
⅜	0.110	.....
½	0.196	0.250
⅝	0.307	.....
¾	0.442	.....
⅞	0.601	.....
1	0.785	1.000
1⅛	.....	1.266
1¼	.....	1.563

The areas of deformed bars shall be determined by the minimum cross-section thereof.

Include under Section VI, on Depositing, Paragraphs 23 to 28, the following provision for Spouting:

Spouting.—When authorized by the engineer, concrete may be conveyed by spouting, in which case the plant shall be of such size and design as to insure a practically continuous flow in the spout. The angle of the spout with the horizontal shall be such as to allow the concrete to flow without separation of the ingredients. The spout shall be thoroughly flushed with water before and after each run. The delivery from the spout shall be as close as possible to the point of deposit. When operation must be intermittent, the spout shall discharge into a hopper.

Appendix B

DEVELOPMENTS IN THE ART OF MAKING CONCRETE

J. E. Freeman, *Chairman;* J. C. Nagle, Noah Johnson, F. W. Leatherbury, *Sub-Committee.*

TENTATIVE SPECIFICATIONS FOR COLD-DRAWN STEEL WIRE FOR CONCRETE REINFORCEMENT*

(From A. S. T. M. Tentative Standards, 1921, p. 33)

Serial Designation: A 82—21 T.

These specifications are issued under the fixed designation A 82; the final number indicates the year of original issue, or in the case of revision, the year of last revision.

Issued, 1921.

Material Covered.

1. These specifications cover cold-drawn steel wire to be used as such, or in fabricated form, for the reinforcement of concrete, in gages not less than 0.080 in. nor greater than 0.500 in.

Basis of Purchase.

2. When wire is ordered by gage number the following relation between number and diameter, in inches, shall apply unless otherwise specified.

Gage Number	*Equivalent Diameter, Inches*	*Gage Number*	*Equivalent Diameter, Inches*
0000000	0.4900	5	0.2070
000000	0.4615	6	0.1920
00000	0.4305	7	0.1770
0000	0.3938	8	0.1620
000	0.3625	9	0.1483
00	0.3310	10	0.1350
0	0.3065	11	0.1205
1	0.2830	12	0.1055
2	0.2625	13	0.0915
3	0.2437	14	0.0800
4	0.2253	..	......

(I) Manufacture

Process.

3. (a) The steel shall be made by either or both the following processes: Bessemer or open-hearth.

Drawing.

(b) The wire shall be cold drawn from rods hot-rolled from billets.

*Criticisms of these Tentative Specifications are solicited and should be directed, preferably before January 1, 1922, to F. M. Waring, Chairman of Committee A-1 on Steel, Pennsylvania System, Altoona, Pa.

(II) Physical Properties and Tests

Tension Tests.

4. (a) The wire, except as specified in paragraphs (b) and (c), shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	80,000
Reduction of area, per cent	30

(b) For wire to be used in the fabrication of mesh a minimum tensile strength of 70,000 lb. per sq. in. shall be permitted.

(c) For wire testing over 100,000 lb. per sq. in. tensile strength the reduction of area shall be not less than 25 per cent.

Bend Tests.

5. The test specimen shall withstand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows:

For wire 0.3 in. in diameter or under a pin the diameter of which is equal to the diameter of the specimen.

For wire over 0.3 in. in diameter, around a pin the diameter of which is equal to twice the diameter of the specimen.

Test Specimens.

6. Tension and bend test specimens shall be of the full-size section of the wire as drawn.

Number of Tests.

7. (a) One tension and one bend test shall be made for each 10 tons or less of each size of wire.

(b) If any test specimen shows defects or develops flaws, it may be discarded and another specimen substituted.

(III) Permissible Variations in Gage

8. The diameter of the wire shall not vary more than 0.003 in. from the size ordered.

(IV) Workmanship and Finish

9. The finished wire shall be free from injurious defects and shall have a workmanlike finish with smooth surface.

(V) Inspection and Rejection

Inspection.

10. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wire is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. Wire which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

ABRAMS' SELECTIVE CONCRETE STRENGTH TESTS

Giving Proportions and Quantities of Materials, using aggregates of different sizes, for concrete of various strengths with different degrees of plasticity as measured by the slump test.

The following tables were prepared by Prof. Duff A. Abrams, based on experimental studies of concrete carried out at the Structural Materials Research Laboratory, through the cooperation of the Portland Cement Association and Lewis Institute. The investigations on which these tables are based covered a period of about seven years and included nearly one hundred thousand tests.

Separate tables of Proportions and Quantities of Materials have been prepared for concrete of compressive strengths of 1,500, 2,000, 2,500, 3,000, 3,500 and 4,000 lb. per sq. in. at the age of 28 days, using fine and coarse aggregate of different sizes and a wide range of consistencies as measured by the slump test.

The proportions are based on the compressive strengths of 6 by 12-in. cylinders made and stored in accordance with the Tentative Methods of Making Compression Tests of Concrete of the American Society for Testing Materials. The principal features of this method are: Aggregates dry and of known sieve analysis, proportion by volume, concrete hand-mixed, puddled in metal cylinder forms, generally 6 by 12 in. in size. Plasticity of concrete controlled by slump test, specimens cured in damp sand and tested in compression at 7 and 28 days.

The quantities of materials per cubic yard of finished concrete given in the tables are *net* quantities, *no allowance* being made for waste. The conditions peculiar to each job should govern waste allowances which the estimator should base on experience or other data available; for average conditions, the following allowances for waste are suggested:

Cement 2 per cent, fine aggregate 10 per cent, coarse aggregate 5 per cent.

The above percentages do not include any allowance for grouting, patching, washing or replacements.

The purpose of the tables is threefold:

(1) To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

(2) To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

(3) To furnish a correct basis for comparing the relative economies of concretes made from aggregates of different sizes when the plasticity and strength of the resulting concrete are taken into account.

The chief value of the tables of Quantities of Materials is in comparative studies of different aggregates and combinations, but they should also prove useful in estimating. The quantities are based on laboratory investigations, with aggregates measured dry and carefully rodded or puddled. Allowance must be made when using the tables for estimating, for the different results obtained when aggregates are measured in the loose condition common to field measurements. There will be but little difference, if any, in the measurement of broken stone or pebbles due to the two methods, but the measurement of sand will show a difference of from 5 to 20 per cent according to the moisture content.

If the proportions to be used in the work are selected from the table without preliminary tests of the materials and control tests are not made during the progress of the work, the mixtures in bold-face type should be used.

The use of these tables as a guide in the selection of concrete mixtures and for comparing different mixtures is based on the following:

(1) Concrete must be plastic;
(2) Aggregates must be clean and structurally sound;
(3) Aggregates must be graded between the sizes indicated;
(4) Cement must meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials.

The plasticity of the concrete shall be determined by the slump test carried out in accordance with the following Tentative Specifications for Workability of Concrete for Concrete Pavements of the American Society for Testing Materials:

> "In determining workability, the newly mixed concrete shall be placed in a truncated *cone-shaped metal mold* 12 in. high, 8 in. in diameter at the base, and 4 in. in diameter at the top, and provided with handles at the sides. The concrete shall be lightly tamped with a rod as it is placed in the mold which, when filled, shall be immediately removed and the slump or settlement of the concrete noted."

Apply the following rules in determining the size to be assigned to a given aggregate:

(1) Sieve analysis shall be made in accordance with the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete, of the American Society for Testing Materials. The principal features of this method are: Representative sample selected by quartering or by use of a sampler; dry samples separated by use of square mesh wire cloth sieves having 100, 50, 30, 16, 8, 4 meshes per linear inch and 3/8, 3/4, 1 1/2 and 3 in. Percentages of sample *coarser than each sieve* computed.

(2). Not less than 15 per cent shall be retained between the sieve which is considered the maximum size and the next smaller sieve.

(3) Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size. (For example: a graded sand with 15 per cent retained on the No. 8 sieve would fall in the O-No. 4 size; if 14 per cent or less were retained, the sand would fall in the O-No. 8 size. A coarse aggregate having 16 per cent coarser than 2-in. sieve would be considered as 3 in. aggregate.)

(4) Only the sieve sizes given in the table shall be considered in applying rules (1) and (2).

Proportions and Quantities of Materials may be interpolated for concrete strengths, aggregate sizes and consistencies not covered by the tables.

October 14, 1921.

QUANTITIES OF MATERIALS FOR CONCRETE OF A GIVEN COMPRESSIVE STRENGTH

By Duff A. Abrams*

These tables are based on experimental studies of concrete carried out through the coöperation of the Portland Cement Association and Lewis Institute. The investigations on which these values are based have covered a period of about seven years and included nearly one hundred thousand tests.

Separate tables of Proportions and Quantities of Materials have been prepared for concrete of strengths of 1500, 2000, 2500, 3000, 3500, and 4000 lb. per sq. in. at the age of 28 days, using fine and coarse aggregate of different sizes and a wide range of consistencies as measured by the slump tests.

The proportions are based on the compressive strength of 6 by 12-in. cylinders, made and stored in accordance with the Tentative Methods of Making Compression Tests of Concrete of the American Society for Testing Materials. The principal features of this method are: Aggregates dry and of known sieve analysis, proportion by volume, concrete hand-mixed; puddled in metal cylinder forms, generally 6 by 12 in. in size. Plasticity of concrete controlled by slump test, specimens cured in damp sand and tested in compression at 7 and 28 days.

The quantities of materials per cubic yard of finished concrete given in the tables are *net* quantities, *no allowance* being made for waste. The conditions peculiar to each job should govern waste allowances which the estimator should base on experience or other data available; for average conditions, the following allowances for waste are suggested:

Cement 2 per cent, fine aggregate 10 per cent, coarse aggregate 5 per cent.

The above percentages do not include any allowance for grouting, patching, washing or replacements.

The purpose of the tables is threefold:

(1) To furnish a guide in the selection of mixtures to be used in preliminary investigations of the strength of concrete from given materials.

(2) To indicate proportions which may be expected to produce concrete of a given strength under average conditions where control tests are not made.

(3) To furnish a correct basis for comparing the relative economies of concrete made from aggregates of different sizes when the plasticity and strength of the resulting concrete are taken into account.

The value of the tables of Quantities of Materials is not in their use for estimating, but in comparative studies of different aggregates and combinations. The quantities are based on laboratory investigations, with aggregates measured dry and carefully rodded or puddled. Allowance must be made when using the tables for estimating, for the different results obtained when aggregates are measured in the loose condition

*Professor in Charge of Structural Materials Research Laboratory, Lewis Institute, Chicago.

common to field measurements. There will be but little difference, if any, in the measurement of broken stone or pebbles due to the two methods, but the measurement of sand will show a difference of from 5 to 20 per cent, according to the moisture content.

If the proportions to be used in the work are selected from the table without preliminary tests of the materials, and control tests are not made during the progress of the work, the mixtures in bold-face type should be used.

The use of these tables as a guide in the selection of concrete mixtures and for comparing different mixtures is based on the following:

(1) Concrete must be plastic;
(2) Aggregates must be clean and structurally sound;
(3) Aggregates must be graded between the sizes indicated;
(4) Cement must meet the requirements of the Standard Specifications and Tests for Portland Cement of the American Society for Testing Materials.

The plasticity of the concrete shall be determined by the slump test carried out in accordance with the following Tentative Specifications for Workability of Concrete for Concrete Pavements of the American Society for Testing Materials:

> "In determining workability, the newly mixed concrete shall be placed in a truncated cone-shaped metal mold 12 in. high, 8 in. in diameter at the base, and 4 in. in diameter at the top, and provided with handles at the sides. The concrete shall be lightly tamped with a rod as it is placed in the mold which, when filled, shall be immediately removed and the slump or settlement of the concrete noted."

Apply the following rules in determining the size to be assigned to a given aggregate:

(1) Sieve analysis shall be made in accordance with the Tentative Method of Test for Sieve Analysis of Aggregates for Concrete, of the American Society for Testing Materials. The principal features of this method are: Representative sample selected by quartering or by use of a sampler; separate dry sample by use of square mesh wire cloth sieves having 100-50, 30-16, 8 and 4 meshes per linear inch and ⅜, ¾, 1½ and 3 in. Compute percentages of sample coarser than each sieve.
(2) Not less than 15 per cent shall be retained between the sieve which is considered the maximum size and the next smaller sieve.
(3) Not more than 15 per cent of a coarse aggregate shall be finer than the sieve considered as the minimum size. (For example: a graded sand with 16 per cent retained on the No. 8 sieve would fall in the 0-No. 4 size; if 14 per cent or less were retained, the sand would fall in the 0-No. 8 size. A coarse aggregate having 16 per cent coarser than 2-in. sieve would be considered as 3-in. aggregate.)
(4) Only the sieve sizes given in the table shall be considered in applying rules (1) and (2).

Proportions and quantities of materials may be interpolated for concrete strengths, aggregate sizes and consistencies not covered by the tables.

Proportions for 1500 lb. per sq. in. Concrete

Based on 28-day compressive strength of 6x12 in. cylinders.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:2.8	1:3.2	1:3.8	1:4.4	1:5.1
	3 " 4	1:2.4	1:2.8	1:3.3	1:3.8	1:4.5
	6 " 7	**1:1.9**	**1:2.2**	**1:2.6**	**1:3.0**	**1:3.6**
	8 " 10	1:1.4	1:1.6	1:1.8	1:2.1	1:2.5
No. 4 to ¾ in.	½ to 1	1:2.6:4.6	1:2.9:4.3	1:3.4:4.1	1:3.9:3.6	1:4.6:3.1
	3 " 4	1:2.3:4.0	1:2.6:3.8	1:2.9:3.6	1:3.4:3.2	1:4.1:2.8
	6 " 7	**1:1.8:3.4**	**1:2.0:3.2**	**1:2.3:3.1**	**1:2.6:2.8**	**1:3.1:2.5**
	8 " 10	1:1.1:2.5	1:1.3:2.4	1:1.5:2.4	1:1.7:2.2	1:2.1:2.0
No. 4 to 1 in.	½ to 1	1:2.4:5.3	1:2.7:5.2	1:3.1:5.0	1:3.5:4.7	1:4.3:4.3
	3 " 4	1:2.1:4.7	1:2.4:4.5	1:2.7:4.4	1:3.1:4.1	1:3.7:3.7
	6 " 7	**1:1.6:3.9**	**1:1.8:3.8**	**1:2.1:3.7**	**1:2.4:3.5**	**1:2.9:3.3**
	8 " 10	1:1.1:2.9	1:1.2:2.8	1:1.4:2.8	1:1.6:2.7	1:1.9:2.5
No. 4 to 1½ in.	½ to 1	1:2.4:6.0	1:2.7:5.9	1:3.1:5.8	1:3.5:5.4	1:4.1:5.1
	3 " 4	1:2.0:5.4	1:2.3:5.3	1:2.7:5.2	1:3.0:5.0	1:3.5:4.6
	6 " 7	**1:1.6:4.4**	**1:1.8:4.3**	**1:2.0:4.3**	**1:2.3:4.1**	**1:2.7:3.9**
	8 " 10	1:1.0:3.3	1:1.1:3.2	1:1.3:3.2	1:1.5:3.1	1:1.8:2.9
No. 4 to 2 in.	½ to 1	1:2.2:6.9	1:2.4:6.8	1:2.8:6.8	1:3.1:6.6	1:3.7:6.4
	3 " 4	1:1.8:6.2	1:2.0:6.1	1:2.4:6.1	1:2.7:6.0	1:3.1:5.7
	6 " 7	**1:1.4:5.1**	**1:1.6:5.0**	**1:1.8:5.0**	**1:2.0:5.0**	**1:2.4:4.8**
	8 " 10	1:0.9:3.8	1:1.0:3.8	1:1.1:3.8	1:1.3:3.8	1:1.5:3.7
⅜ to 1 in.	½ to 1	1:2.8:5.2	1:3.1:5.1	1:3.6:4.8	1:4.2:4.6	1:4.8:4.1
	3 " 4	1:2.4:4.5	1:2.6:4.5	1:3.1:4.3	1:3.6:4.0	1:4.1:3.6
	6 " 7	**1:1.9:3.9**	**1:2.1:3.7**	**1:2.4:3.6**	**1:2.8:3.4**	**1:3.2:3.1**
	8 " 10	1:1.3:2.8	1:1.4:2.8	1:1.6:2.7	1:1.9:2.6	1:2.2:2.4
⅜ to 1½ in.	½ to 1	1:2.8:5.8	1:3.1:5.7	1:3.5:5.5	1:4.1:5.3	1:4.7:4.9
	3 " 4	1:2.4:5.2	1:2.7:5.1	1:3.1:5.0	1:3.5:4.8	1:4.1:4.4
	6 " 7	**1:1.9:4.3**	**1:2.1:4.2**	**1:2.4:4.2**	**1:2.7:4.0**	**1:3.1:3.7**
	8 " 10	1:1.2:3.2	1:1.4:3.2	1:1.6:3.1	1:1.8:3.0	1:2.1:2.9
⅜ to 2 in.	½ to 1	1:2.7:6.6	1:3.0:6.6	1:3.4:6.5	1:3.9:6.4	1:4.4:6.0
	3 " 4	1:2.3:5.9	1:2.6:5.9	1:2.9:5.8	1:3.3:5.6	1:3.7:5.5
	6 " 7	**1:1.8:4.9**	**1:2.0:4.8**	**1:2.2:4.8**	**1:2.6:4.8**	**1:3.0:4.5**
	8 " 10	1:1.2:3.7	1:1.3:3.7	1:1.5:3.7	1:1.7:3.6	1:1.9:3.5
¾ to 1½ in.	½ to 1	1:3.2:5.4	1:3.6:5.3	1:4.1:5.1	1:4.7:4.8	1:5.3:4.4
	3 " 4	1:2.8:4.8	1:3.2:4.8	1:3.6:4.6	1:4.0:4.4	1:4.6:4.0
	6 " 7	**1:2.1:4.0**	**1:2.5:4.0**	**1:2.8:3.9**	**1:3.2:3.7**	**1:3.5:3.4**
	8 " 10	1:1.5:3.0	1:1.7:3.0	1:1.9:2.9	1:2.2:2.8	1:2.5:2.7
¾ to 2 in.	½ to 1	1:3.2:6.2	1:3.6:6.1	1:4.0:6.0	1:4.6:5.8	1:5.2:5.4
	3 " 4	1:2.8:5.5	1:3.1:5.5	1:3.5:5.4	1:3.9:5.2	1:4.5:4.9
	6 " 7	**1:2.1:4.5**	**1:2.4:4.6**	**1:2.7:4.5**	**1:3.1:4.4**	**1:3.5:4.1**
	8 " 10	1:1.4:3.4	1:1.6:3.4	1:1.8:3.4	1:2.1:3.4	1:2.4:3.3
¾ to 3 in.	½ to 1	1:3.2:7.1	1:3.6:7.1	1:4.0:7.0	1:4.6:6.9	1:5.2:6.6
	3 " 4	1:2.7:6.3	1:3.0:6.3	1:3.4:6.3	1:4.0:6.2	1:4.5:5.9
	6 " 7	**1:2.1:5.1**	**1:2.4:5.2**	**1:2.7:5.2**	**1:3.1:5.1**	**1:3.5:4.9**
	8 " 10	1:1.4:3.8	1:1.6:3.9	1:1.8:3.9	1:2.1:3.9	1:2.4:3.8

Quantities of Materials for 1 cu. yd. of 1500 lb. per sq. in. Concrete

The volume of cement is expressed in barrels and of aggregates in cubic yards.
F = fine aggregate; C = coarse aggregate.

Quantities are net, no allowance being made for waste: for average conditions, the following additions are suggested: Cement, 2%; fine aggregate, 10%; coarse aggregate, 5%.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-3/8 in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	1.90	.79		1.77	.84		1.60	.90		1.36	.89		1.27	.96	
	3 " 4	2.12	.75		1.96	.81		1.75	.86		1.52	.86		1.38	.92	
	6 " 7	**2.49**	**.70**		**2.33**	**.76**		**2.08**	**.80**		**1.81**	**.80**		**1.64**	**.88**	
	8 " 10	2.98	.62		2.82	.67		2.36	.70		2.32	.72		2.10	.78	
No. 4 to ¾ in.	½ to 1	1.02	.39	.69	1.02	.44	.66	1.01	.51	.61	.98	.56	.52	.98	.67	.45
	3 " 4	1.17	.40	.69	1.12	.43	.63	1.11	.48	.59	1.07	.54	.51	1.08	.65	.45
	6 " 7	**1.39**	**.37**	**.70**	**1.36**	**.40**	**.64**	**1.31**	**.45**	**.60**	**1.30**	**.50**	**.54**	**1.27**	**.58**	**.47**
	8 " 10	1.76	.29	.65	1.76	.34	.63	1.73	.38	.61	1.68	.42	.55	1.67	.52	.49
No. 4 to 1 in.	½ to 1	.98	.35	.77	.98	.39	.75	.96	.44	.71	.94	.49	.65	.93	.59	.59
	3 " 4	1.08	.34	.75	1.06	.38	.70	1.05	.42	.68	1.02	.47	.62	1.02	.56	.56
	6 " 7	**1.32**	**.31**	**.76**	**1.30**	**.35**	**.73**	**1.23**	**.38**	**.67**	**1.21**	**.43**	**.63**	**1.21**	**.52**	**.59**
	8 " 10	1 70	.28	.73	1.68	.30	.70	1.64	.34	.68	1.60	.38	.64	1.57	.44	.58
No. 4 to 1½ in.	½ to 1	.93	.33	.83	.93	.37	.81	.91	.42	.78	.88	.46	.70	.86	.52	.65
	3 " 4	1.02	.30	.81	1.03	.35	.81	1.01	.40	.78	.98	.43	.72	.97	.50	.66
	6 " 7	**1.24**	**.29**	**.81**	**1.23**	**.33**	**.78**	**1.18**	**.35**	**.75**	**1.12**	**.38**	**.68**	**1.15**	**.46**	**.66**
	8 " 10	1.62	.24	.79	1.59	.26	.75	1.54	.30	.73	1.50	.33	.69	1.50	.40	.64
No. 4 to 2 in.	½ to 1	.88	.29	.90	.88	.31	.88	.85	.35	.86	.82	.38	.80	.80	.44	.76
	3 " 4	.98	.26	.90	.99	.29	.89	.96	.34	.87	.93	.37	.82	.91	.42	.77
	6 " 7	**1.17**	**.27**	**.88**	**1.16**	**.28**	**.86**	**1.13**	**.30**	**.84**	**1.09**	**.32**	**.81**	**1.09**	**.39**	**.78**
	8 " 10	1.53	.20	.86	1.49	.22	.84	1.46	.24	.82	1.43	.27	.80	1.43	.32	.78
⅜ to 1 in.	½ to 1	1.00	.41	.77	.97	.44	.73	.95	.51	.68	.91	.56	.62	.92	.65	.56
	3 " 4	1.08	.38	.72	1.05	.40	.70	1.03	.47	.65	1.00	.53	.59	1.02	.62	.54
	6 " 7	**1.32**	**.37**	**.76**	**1.27**	**.40**	**.70**	**1.25**	**.44**	**.67**	**1.20**	**.50**	**.60**	**1.21**	**.57**	**.56**
	8 " 10	1.73	.33	.72	1.69	.35	.70	1.66	.39	.66	1.59	.45	.61	1.54	.50	.55
⅜ to 1½ in.	½ to 1	.93	.38	.80	.91	.42	.77	.90	.47	.73	.85	.52	.67	.85	.59	.62
	3 " 4	1.03	.37	.79	1.01	.40	.76	1.00	.46	.74	.95	.49	.68	.96	.58	.62
	6 " 7	**1.22**	**.34**	**.78**	**1.21**	**.38**	**.75**	**1.18**	**.42**	**.73**	**1.17**	**.47**	**.69**	**1.13**	**.52**	**.62**
	8 " 10	1.62	.29	.77	1.60	.33	.76	1.54	.36	.71	1.48	.39	.66	1.46	.45	.63
⅜ to 2 in.	½ to 1	.88	.35	.86	.86	.38	.84	.83	.42	.80	.79	.45	.75	.77	.50	.68
	3 " 4	.98	.33	.85	.97	.37	.85	.95	.41	.81	.91	.44	.75	.90	.49	.73
	6 " 7	**1.16**	**.31**	**.84**	**1.14**	**.34**	**.81**	**1.11**	**.36**	**.79**	**1.08**	**.42**	**.77**	**1.07**	**.48**	**.71**
	8 " 10	1.51	.28	.87	1.50	.29	.82	1.45	.32	.79	1.40	.35	.75	1.38	.39	.71
¾ to 1½ in.	½ to 1	.91	.43	.73	.89	.47	.70	.87	.53	.66	.82	.57	.58	.81	.63	.53
	3 " 4	1.00	.41	.71	1.00	.47	.71	.97	.52	.66	.93	.55	.60	.91	.62	.54
	6 " 7	**1.20**	**.37**	**.71**	**1.20**	**.44**	**.71**	**1.15**	**.48**	**.66**	**1.11**	**.53**	**.61**	**1.08**	**.56**	**.54**
	8 " 10	1.60	.36	.71	1.57	.39	.70	1.52	.43	.65	1.44	.47	.60	1.43	.53	.57
¾ to 2 in.	½ to 1	.85	.40	.78	.85	.45	.77	.80	.47	.71	.76	.52	.65	.74	.57	.59
	3 " 4	.96	.40	.78	.95	.44	.77	.92	.48	.73	.84	.48	.65	.86	.57	.62
	6 " 7	**1.14**	**.35**	**.76**	**1.14**	**.41**	**.78**	**1.08**	**.43**	**.72**	**1.03**	**.47**	**.67**	**1.04**	**.54**	**.63**
	8 " 10	1.50	.31	.75	1.46	.35	.73	1.43	.38	.72	1.37	.43	.69	1.34	.48	.65
¾ to 3 in.	½ to 1	.78	.37	.82	.76	.40	.80	.72	.43	.75	.67	.46	.68	.65	.50	.63
	3 " 4	.91	.36	.85	.89	.40	.83	.86	.43	.80	.81	.48	.74	.79	.53	.69
	6 " 7	**1.04**	**.32**	**.79**	**1.04**	**.37**	**.80**	**1.03**	**.41**	**.79**	**.98**	**.45**	**.88**	**.99**	**.51**	**.72**
	8 " 10	1.43	.30	.80	1.39	.33	.80	1.35	.36	.78	1.30	.40	.75	1.25	.44	.70

Proportions for 2000 lb. per sq. in. Concrete

Based on 28-day compressive strength of 6x12 in. cylinders.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:2.2	1:2.6	1:3.0	1:3.5	1:4.1
	3 " 4	1:1.9	1:2.2	1:2.6	1:3.0	1:3.5
	6 " 7	**1:1.5**	**1:1.7**	**1:2.0**	**1:2.3**	**1:2.7**
	8 " 10	1:1.0	1:1.1	1:1.3	1:1.6	1:1.8
No. 4 to ¾ in.	½ to 1	1:2.1:3.8	1:2.3:3.7	1:2.6:3.5	1:3.0:3.1	1:3.6:2.8
	3 " 4	1:1.7:3.3	1:1.9:3.2	1:2.2:3.1	1:2.6:2.8	1:3.0:2.4
	6 " 7	**1:1.3:2.7**	**1:1.4:2.6**	**1:1.7:2.5**	**1:1.9:2.3**	**1:2.3:2.1**
	8 " 10	1:0.8:1.9	1:0.9:1.9	1:1.0:1.8	1:1.2:1.7	1:1.5:1.6
No. 4 to 1 in.	½ to 1	1:1.9:4.5	1:2.2:4.3	1:2.5:4.2	1:2.8:3.9	1:3.4:3.6
	3 " 4	1:1.6:3.9	1:1.8:3.8	1:2.1:3.7	1:2.4:3.5	1:2.8:3.2
	6 " 7	**1:1.2:3.1**	**1:1.3:3.1**	**1:1.5:3.0**	**1:1.8:2.9**	**1:2.1:2.7**
	8 " 10	1:0.7:2.2	1:0.8:2.2	1:1.0:2.3	1:1.1:2.1	1:1.3:2.0
No. 4 to 1½ in.	½ to 1	1:1.9:5.0	1:2.1:4.9	1:2.4:4.9	1:2.7:4.6	1:3.2:4.4
	3 " 4	1:1.6:4.4	1:1.7:4.3	1:2.0:4.2	1:2.4:4.0	1:2.7:3.8
	6 " 7	**1:1.1:3.5**	**1:1.3:3.5**	**1:1.4:3.5**	**1:1.7:3.4**	**1:2.0:3.2**
	8 " 10	1:0.7:2.5	1:0.8:2.5	1:0.9:2.5	1:1.0:2.4	1:1.2:2.3
No. 4 to 2 in.	½ to 1	1:1.7:5.8	1:1.9:5.7	1:2.1:5.8	1:2.4:5.6	1:2.8:5.5
	3 " 4	1:1.4:5.0	1:1.5:5.0	1:1.8:5.0	1:2.0:4.9	1:2.3:4.7
	6 " 7	**1:1.0:4.1**	**1:1.1:4.1**	**1:1.2:4.1**	**1:1.4:4.1**	**1:1.7:3.9**
	8 " 10	1:0.6:2.9	1:0.7:2.9	1:0.7:3.0	1:0.8:2.9	1:1.0:2.9
⅜ to 1 in.	½ to 1	1:2.2:4.4	1:2.5:4.2	1:2.8:4.1	1:3.3:3.8	1:3.8:3.4
	3 " 4	1:1.9:3.8	1:2.1:3.7	1:2.4:3.6	1:2.8:3.4	1:3.2:3.1
	6 " 7	**1:1.4:3.1**	**1:1.5:3.0**	**1:1.8:3.0**	**1:2.1:2.8**	**1:2.4:2.5**
	8 " 10	1:0.9:2.2	1:1.0:2.2	1:1.1:2.2	1:1.3:2.0	1:1.5:1.9
⅜ to 1½ in.	½ to 1	1:2.2:4.9	1:2.5:4.8	1:2.8:4.7	1:3.2:4.6	1:3.7:4.2
	3 " 4	1:1.9:4.3	1:2.1:4.2	1:2.4:4.1	1:2.7:4.0	1:3.1:3.7
	6 " 7	**1:1.4:3.5**	**1:1.5:3.4**	**1:1.7:3.4**	**1:2.0:3.3**	**1:2.3:3.1**
	8 " 10	1:0.9:2.5	1:1.0:2.5	1:1.1:2.4	1:1.3:2.4	1:1.5:2.3
⅜ to 2 in.	½ to 1	1:2.1:5.6	1:2.3:5.5	1:2.6:5.5	1:3.0:5.4	1:3.5:5.1
	3 " 4	1:1.7:4.8	1:2.0:4.8	1:2.2:4.8	1:2.5:4.7	1:2.9:4.4
	6 " 7	**1:1.3:4.0**	**1:1.4:3.9**	**1:1.6:3.9**	**1:1.8:3.9**	**1:2.1:3.8**
	8 " 10	1:0.8:2.9	1:0.9:2.9	1:1.0:2.9	1:1.2:2.9	1:1.3:2.8
¾ to 1½ in.	½ to 1	1:2.6:4.5	1:2.9:4.5	1:3.3:4.4	1:3.8:4.2	1:4.3:3.9
	3 " 4	1:2.2:3.9	1:2.5:3.9	1:2.8:3.8	1:3.2:3.6	1:3.6:3.3
	6 " 7	**1:1.6:3.2**	**1:1.8:3.2**	**1:2.1:3.1**	**1:2.4:3.0**	**1:2.7:2.8**
	8 " 10	1:1.0:2.3	1:1.2:2.3	1:1.4:2.2	1:1.6:2.2	1:1.8:2.1
¾ to 2 in.	½ to 1	1:2.5:5.2	1:2.8:5.2	1:3.2:5.1	1:3.6:5.0	1:4.1:4.7
	3 " 4	1:2.1:4.5	1:2.4:4.5	1:2.7:4.4	1:3.1:4.3	1:3.5:4.0
	6 " 7	**1:1.6:3.7**	**1:1.8:3.7**	**1:2.0:3.7**	**1:2.3:3.6**	**1:2.6:3.5**
	8 " 10	1:1.0:2.6	1:1.1:2.7	1:1.3:2.6	1:1.5:2.7	1:1.7:2.6
¾ to 3 in.	½ to 1	1:2.5:6.0	1:2.9:5.9	1:3.2:5.9	1:3.6:5.8	1:4.1:5.6
	3 " 4	1:2.1:5.1	1:2.4:5.2	1:2.7:5.2	1:3.1:5.1	1:3.5:4.9
	6 " 7	**1:1.5:4.1**	**1:1.7:4.2**	**1:2.0:4.2**	**1:2.3:4.2**	**1:2.5:4.0**
	8 " 10	1:1.0:2.9	1:1.1:3.0	1:1.3:3.0	1:1.5:3.0	1:1.7:3.0

Quantities of Materials for 1 cu. yd. of 2000 lb. per sq. in. Concrete

The volume of cement is expressed in barrels and of aggregates in cubic yards.
F = fine aggregate; C = coarse aggregate.

Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2%; fine aggregate, 10%; coarse aggregate, 5%.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	2.31	.75		2.12	.82		1.92	.85		1.65	.85		1.42	.86	
	3 " 4	2.55	.72		2.39	.78		2.12	.82		1.85	.82		1.71	.89	
	6 " 7	**2.94**	**.65**		**2.83**	**.71**		**2.52**	**.75**		**2.24**	**.76**		**2.06**	**.83**	
	8 " 10	3.60	.53		3.54	.58		3.25	.62		2.80	.66		2.62	.70	
No. 4 to ¾ in..	½ to 1	1.27	.40	.71	1.24	.42	.68	1.19	.46	.62	1.17	.52	.54	1.17	.62	.48
	3 " 4	1.43	.36	.70	1.40	.39	.66	1.36	.44	.62	1.34	.51	.56	1.32	.59	.47
	6 " 7	**1.71**	**.33**	**.68**	**1.70**	**.35**	**.66**	**1.66**	**.42**	**.61**	**1.60**	**.45**	**.54**	**1.59**	**.54**	**.50**
	8 " 10	2.25	.27	.63	2.23	.30	.63	2.20	.33	.59	2.13	.38	.54	2.10	.47	.50
No. 4 to 1 in...	½ to 1	1.19	.33	.79	1.17	.38	.74	1.13	.42	.70	1.10	.46	.64	1.09	.55	.58
	3 " 4	1.36	.32	.78	1.32	.35	.74	1.26	.39	.69	1.24	.44	.64	1.24	.51	.59
	6 " 7	**1.65**	**.29**	**.76**	**1.62**	**.31**	**.74**	**1.56**	**.35**	**.69**	**1.52**	**.40**	**.65**	**1.51**	**.47**	**.60**
	8 " 10	2.15	.22	.70	2.13	.25	.69	2.07	.31	.70	2.01	.33	.63	1.98	.38	.59
No. 4 to 1½ in.	½ to 1	1.10	.31	.81	1.09	.34	.79	1.07	.38	.78	1.05	.42	.71	1.04	.49	.68
	3 " 4	1.26	.30	.82	1.25	.31	.79	1.20	.35	.74	1.17	.42	.69	1.16	.46	.65
	6 " 7	**1.54**	**.25**	**.80**	**1.52**	**.29**	**.79**	**1.47**	**.30**	**.76**	**1.44**	**.36**	**.72**	**1.43**	**.42**	**.68**
	8 " 10	2.04	.21	.75	2.00	.24	.74	1.94	.26	.72	1.88	.28	.67	1.88	.33	.64
No. 4 to 2 in...	½ to 1	1.04	.26	.89	1.05	.29	.88	1.04	.32	.89	1.00	.35	.83	.98	.41	.80
	3 " 4	1.20	.25	.89	1.19	.26	.88	1.16	.31	.86	1.11	.33	.80	1.12	.38	.78
	6 " 7	**1.47**	**.22**	**.89**	**1.45**	**.24**	**.88**	**1.38**	**.25**	**.84**	**1.35**	**.28**	**.82**	**1.36**	**.34**	**.79**
	8 " 10	1.92	.17	.82	1.89	.20	.81	1.85	.19	.82	1.81	.21	.78	1.80	.27	.77
⅜ to 1 in......	½ to 1	1.17	.38	.76	1.16	.43	.72	1.12	.46	.68	1.10	.54	.62	1.10	.62	.55
	3 " 4	1.34	.38	.75	1.33	.41	.73	1.29	.46	.69	1.23	.51	.62	1.23	.58	.56
	6 " 7	**1.67**	**.35**	**.77**	**1.63**	**.36**	**.72**	**1.57**	**.42**	**.70**	**1.51**	**.47**	**.63**	**1.53**	**.54**	**.57**
	8 " 10	2.16	.29	.70	2.12	.31	.69	2.06	.34	.67	2.01	.39	.60	1.93	.43	.54
⅜ to 1½ in....	½ to 1	1.10	.36	.80	1.07	.40	.76	1.05	.43	.73	1.02	.48	.69	1.03	.56	.64
	3 " 4	1.25	.35	.79	1.24	.39	.77	1.21	.43	.73	1.16	.46	.69	1.15	.53	.63
	6 " 7	**1.54**	**.32**	**.80**	**1.52**	**.34**	**.77**	**1.47**	**.37**	**.74**	**1.42**	**.42**	**.69**	**1.41**	**.48**	**.65**
	8 " 10	2.05	.27	.76	2.00	.29	.74	1.93	.31	.70	1.89	.36	.67	1.83	.41	.62
⅜ to 2 in......	½ to 1	1.05	.33	.85	1.03	.35	.84	1.01	.39	.82	.98	.43	.78	.97	.50	.73
	3 " 4	1.19	.30	.85	1.18	.35	.84	1.14	.37	.81	1.10	.41	.76	1.09	.47	.71
	6 " 7	**1.46**	**.28**	**.86**	**1.45**	**.30**	**.84**	**1.40**	**.33**	**.81**	**1.33**	**.35**	**.77**	**1.31**	**.41**	**.74**
	8 " 10	1.91	.23	.82	1.88	.25	.81	1.83	.27	.79	1.80	.32	.77	1.74	.34	.72
¾ to 1½ in....	½ to 1	1.07	.41	.71	1.06	.45	.71	1.02	.50	.66	.98	.55	.61	.98	.62	.57
	3 " 4	1.23	.40	.71	1.23	.45	.71	1.19	.49	.67	1.12	.53	.60	1.10	.59	.54
	6 " 7	**1.51**	**.36**	**.72**	**1.49**	**.40**	**.71**	**1.45**	**.45**	**.67**	**1.36**	**.48**	**.60**	**1.36**	**.54**	**.56**
	8 " 10	2.01	.30	.69	1.97	.35	.67	1.91	.40	.62	1.81	.43	.59	1.79	.48	.56
¾ to 2 in......	½ to 1	1.02	.38	.79	1.02	.42	.78	.99	.47	.75	.94	.50	.70	.93	.56	.65
	3 " 4	1.17	.36	.78	1.16	.41	.77	1.11	.44	.72	1.05	.48	.67	1.04	.54	.61
	6 " 7	**1.44**	**.34**	**.79**	**1.41**	**.38**	**.77**	**1.37**	**.41**	**.75**	**1.31**	**.45**	**.70**	**1.26**	**.48**	**.65**
	8 " 10	1.88	.28	.72	1.85	.30	.74	1.82	.35	.70	1.74	.39	.69	1.70	.43	.65
¾ to 3 in......	½ to 1	.96	.36	.85	.95	.41	.83	.92	.44	.80	.88	.47	.75	.86	.52	.71
	3 " 4	1.08	.34	.81	1.08	.38	.83	1.05	.42	.81	1.00	.46	.76	.98	.51	.71
	6 " 7	**1.36**	**.30**	**.83**	**1.30**	**.33**	**.81**	**1.28**	**.38**	**.80**	**1.23**	**.42**	**.77**	**1.20**	**.44**	**.71**
	8 " 10	1.81	.27	.78	1.76	.29	.78	1.72	.33	.76	1.65	.37	.73	1.60	.40	.71

Proportions for 2500 lb. per sq. in. Concrete

Based on 28-day compressive strength of 6x12 in. cylinders.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate	Slump, In.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:1.8	1:2.1	1:2.4	1:2.9	1:3.3
	3 " 4	1:1.5	1:1.8	1:2.1	1:2.4	1:2.8
	6 " 7	**1:1.1**	**1:1.3**	**1:1.6**	**1:1.8**	**1:2.1**
	8 " 10	1:0.7	1:0.8	1:0.9	1:1.1	1:1.3
No. 4 to ¾ in.	½ to 1	1:1.6:3.2	1:1.8:3.1	1:2.1:3.0	1:2.4:2.7	1:2.9:2.4
	3 " 4	1:1.3:2.8	1:1.5:2.7	1:1.7:2.6	1:2.0:2.4	1:2.4:2.2
	6 " 7	**1:1.0:2.2**	**1:1.1:2.2**	**1:1.3:2.1**	**1:1.5:2.0**	**1:1.8:1.8**
	8 " 10	1:0.5:1.4	1:0.6:1.4	1:0.7:1.4	1:0.8:1.4	1:1.0:1.3
No. 4 to 1 in.	½ to 1	1:1.5:3.7	1:1.7:3.7	1:2.0:3.5	1:2.2:3.4	1:2.7:3.1
	3 " 4	1:1.2:3.3	1:1.4:3.2	1:1.6:3.1	1:1.9:3.0	1:2.2:2.7
	6 " 7	**1:0.9:2.6**	**1:1.0:2.5**	**1:1.1:2.5**	**1:1.3:2.4**	**1:1.6:2.3**
	8 " 10	1:0.5:1.7	1:0.6:1.7	1:0.6:1.7	1:0.7:1.6	1:0.9:1.5
No. 4 to 1½ in.	½ to 1	1:1.4:4.2	1:1.6:4.1	1:1.9:4.1	1:2.2:4.0	1:2.5:3.8
	3 " 4	1:1.2:3.7	1:1.3:3.6	1:1.5:3.6	1:1.8:3.5	1:2.1:3.3
	6 " 7	**1:0.9:2.9**	**1:0.9:2.8**	**1:1.1:2.8**	**1:1.3:2.8**	**1:1.5:2.6**
	8 " 10	1:0.5:1.9	1:0.5:1.9	1:0.6:1.9	1:0.7:1.8	1:0.8:1.8
No. 4 to 2 in.	½ to 1	1:1.3:4.9	1:1.4:4.8	1:1.6:4.9	1:1.9:4.8	1:2.2:4.7
	3 " 4	1:1.1:4.3	1:1.2:4.2	1:1.3:4.3	1:1.6:4.2	1:1.8:4.1
	6 " 7	**1:0.7:3.3**	**1:0.8:3.3**	**1:0.9:3.4**	**1:1.1:3.3**	**1:1.2:3.3**
	8 " 10	1:0.4:2.2	1:0.4:2.2	1:0.5:2.2	1:0.6:2.2	1:0.6:2.2
⅜ to 1 in.	½ to 1	1:1.8:3.7	1:2.0:3.6	1:2.3:3.5	1:2.6:3.3	1:3.0:2.9
	3 " 4	1:1.4:3.2	1:1.6:3.1	1:1.9:2.9	1:2.2:2.9	1:2.5:2.6
	6 " 7	**1:1.0:2.5**	**1:1.2:2.5**	**1:1.3:2.4**	**1:1.6:2.3**	**1:1.8:2.2**
	8 " 10	1:0.6:1.6	1:0.7:1.6	1:0.8:1.6	1:0.9:1.6	1:1.0:1.5
⅜ to 1½ in.	½ to 1	1:1.7:4.1	1:1.9:4.1	1:2.2:4.0	1:2.5:3.9	1:2.9:3.6
	3 " 4	1:1.5:3.6	1:1.6:3.6	1:1.8:3.5	1:2.1:3.4	1:2.3:3.2
	6 " 7	**1:1.0:2.9**	**1:1.2:2.8**	**1:1.3:2.8**	**1:1.5:2.7**	**1:1.8:2.6**
	8 " 10	1:0.6:1.9	1:0.6:1.9	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8
⅜ to 2 in.	½ to 1	1:1.7:4.7	1:1.8:4.7	1:2.1:4.7	1:2.4:4.6	1:2.7:4.4
	3 " 4	1:1.4:4.1	1:1.5:4.1	1:1.7:4.1	1:2.0:4.0	1:2.3:3.9
	6 " 7	**1:1.0:3.2**	**1:1.1:3.2**	**1:1.2:3.2**	**1:1.4:3.2**	**1:1.6:3.1**
	8 " 10	1:0.5:2.1	1:0.6:2.1	1:0.7:2.2	1:0.8:2.2	1:0.9:2.1
¾ to 1½ in.	½ to 1	1:2.0:3.8	1:2.3:3.8	1:2.6:3.7	1:3.0:3.6	1:3.4:3.3
	3 " 4	1:1.7:3.3	1:2.0:3.3	1:2.2:3.2	1:2.5:3.2	1:2.9:2.9
	6 " 7	**1:1.2:2.6**	**1:1.4:2.6**	**1:1.6:2.6**	**1:1.9:2.5**	**1:2.1:2.3**
	8 " 10	1:0.7:1.7	1:0.8:1.7	1:0.9:1.7	1:1.1:1.7	1:1.2:1.6
¾ to 2 in.	½ to 1	1:2.0:4.4	1:2.2:4.4	1:2.5:4.3	1:2.9:4.3	1:3.3:4.1
	3 " 4	1:1.7:3.8	1:1.9:3.8	1:2.1:3.8	1:2.5:3.7	1:2.8:3.6
	6 " 7	**1:1.2:3.0**	**1:1.4:3.0**	**1:1.5:3.0**	**1:1.8:3.0**	**1:2.0:2.8**
	8 " 10	1:0.7:2.0	1:0.8:2.0	1:0.9:2.0	1:1.0:2.0	1:1.2:2.0
¾ to 3 in.	½ to 1	1:2.0:5.0	1:2.2:5.0	1:2.5:5.0	1:2.7:5.0	1:3.2:4.7
	3 " 4	1:1.7:4.3	1:1.9:4.3	1:2.1:4.3	1:2.4:4.3	1:2.7:4.1
	6 " 7	**1:1.2:3.3**	**1:1.4:3.4**	**1:1.5:3.4**	**1:1.8:3.4**	**1:2.0:3.3**
	8 " 10	1:0.7:2.2	1:0.8:2.2	1:0.9:2.2	1:1.0:2.3	1:1.2:2.3

Quantities of Materials for 1 cu. yd. of 2500 lb. per sq. in. Concrete

The volume of cement is expressed in barrels and of aggregates in cubic yards.
F = fine aggregate; C = coarse aggregate.

Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2%; fine aggregate, 10%; coarse aggregate, 5%.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	2.71	.72		2.53	.79		2.30	.82		1.94	.83		1.83	.89	
	3 " 4	3.01	.67		2.78	.74		2.50	.78		2.20	.78		2.05	.85	
	6 " 7	3.60	.59		3.38	.65		2.97	.70		2.71	.72		2.45	.76	
	8 " 10	4.24	.44		4.11	.49		3.91	.52		3.46	.56		3.16	.61	
No. 4 to ¾ in.	½ to 1	1.49	.35	.70	1.46	.39	.67	1.42	.44	.63	1.39	.49	.55	1.39	.60	.49
	3 " 4	1.68	.32	.70	1.67	.37	.67	1.63	.41	.63	1.57	.46	.56	1.54	.55	.50
	6 " 7	2.06	.30	.67	2.03	.33	.66	1.98	.38	.62	1.89	.42	.56	1.89	.50	.50
	8 " 10	2.83	.21	.59	2.78	.25	.58	2.71	.28	.56	2.64	.31	.55	2.58	.38	.50
No. 4 to 1 in.	½ to 1	1.42	.32	.78	1.39	.35	.76	1.35	.40	.70	1.30	.42	.65	1.29	.51	.59
	3 " 4	1.61	.29	.79	1.56	.32	.74	1.51	.36	.69	1.48	.41	.65	1.47	.48	.59
	6 " 7	1.95	.26	.75	1.90	.28	.70	1.87	.30	.69	1.82	.35	.65	1.81	.43	.62
	8 " 10	2.68	.19	.65	2.64	.23	.66	2.54	.23	.64	2.50	.26	.59	2.58	.33	.55
No. 4 to 1½ in.	½ to 1	1.34	.27	.83	1.32	.31	.80	1.25	.35	.76	1.23	.40	.73	1.23	.45	.69
	3 " 4	1.50	.27	.82	1.48	.28	.79	1.43	.32	.76	1.39	.37	.72	1.39	.43	.68
	6 " 7	1.83	.24	.79	1.83	.24	.76	1.78	.29	.74	1.73	.33	.72	1.72	.38	.66
	8 " 10	2.50	.19	.70	2.49	.18	.70	2.42	.21	.68	2.40	.25	.64	2.39	.28	.64
No. 4 to 2 in.	½ to 1	1.25	.24	.91	1.24	.26	.88	1.21	.29	.88	1.17	.33	.83	1.13	.37	.79
	3 " 4	1.44	.23	.92	1.41	.25	.88	1.36	.26	.87	1.31	.31	.81	1.32	.35	.80
	6 " 7	1.77	.18	.87	1.75	.21	.86	1.70	.23	.86	1.65	.27	.81	1.63	.29	.80
	8 " 10	2.43	.14	.79	2.42	.14	.79	2.38	.18	.78	2.32	.21	.75	2.31	.20	.75
⅜ to 1 in.	½ to 1	1.41	.38	.77	1.39	.41	.74	1.34	.46	.69	1.29	.50	.63	1.29	.57	.55
	3 " 4	1.61	.33	.76	1.57	.37	.72	1.51	.42	.65	1.47	.48	.63	1.45	.54	.56
	6 " 7	1.97	.29	.73	1.91	.34	.71	1.87	.36	.66	1.83	.43	.62	1.78	.47	.58
	8 " 10	2.64	.23	.62	2.62	.27	.62	2.56	.30	.61	2.47	.33	.58	2.42	.36	.54
⅜ to 1½ in.	½ to 1	1.32	.33	.80	1.30	.37	.79	1.27	.41	.75	1.22	.45	.70	1.21	.52	.64
	3 " 4	1.49	.33	.79	1.48	.35	.79	1.43	.38	.74	1.38	.43	.69	1.37	.47	.65
	6 " 7	1.86	.28	.80	1.83	.33	.76	1.77	.34	.74	1.73	.38	.69	1.68	.45	.65
	8 " 10	2.49	.22	.70	2.46	.22	.69	2.41	.29	.64	2.38	.32	.63	2.32	.34	.62
⅜ to 2 in.	½ to 1	1.24	.31	.86	1.23	.33	.85	1.09	.34	.76	1.15	.41	.78	1.12	.45	.73
	3 " 4	1.41	.29	.85	1.40	.31	.85	1.35	.34	.82	1.29	.38	.76	1.28	.44	.74
	6 " 7	1.77	.26	.84	1.74	.28	.82	1.68	.30	.80	1.62	.34	.77	1.58	.38	.73
	8 " 10	2.41	.18	.75	2.37	.21	.74	2.32	.24	.76	2.30	.27	.75	2.22	.30	.69
¾ to 1½ in.	½ to 1	1.30	.38	.73	1.29	.44	.72	1.21	.47	.66	1.18	.52	.63	1.16	.58	.57
	3 " 4	1.47	.37	.72	1.45	.43	.71	1.40	.46	.66	1.35	.50	.64	1.32	.57	.57
	6 " 7	1.80	.32	.69	1.80	.37	.69	1.75	.42	.67	1.67	.47	.62	1.64	.51	.56
	8 " 10	2.48	.26	.63	2.45	.29	.62	2.40	.32	.60	2.31	.38	.58	2.27	.40	.54
¾ to 2 in.	½ to 1	1.22	.36	.79	1.22	.40	.79	1.18	.44	.75	1.10	.47	.70	1.07	.52	.65
	3 " 4	1.41	.35	.79	1.38	.39	.77	1.33	.41	.75	1.27	.47	.69	1.23	.51	.65
	6 " 7	1.74	.31	.77	1.70	.35	.76	1.66	.37	.74	1.58	.42	.70	1.53	.45	.64
	8 " 10	2.40	.25	.71	2.36	.28	.70	2.29	.31	.68	2.22	.33	.66	2.17	.38	.64
¾ to 3 in.	½ to 1	1.15	.34	.85	1.13	.37	.84	1.10	.41	.81	1.05	.42	.78	1.02	.48	.71
	3 " 4	1.33	.33	.84	1.30	.37	.83	1.25	.39	.79	1.21	.43	.77	1.18	.47	.72
	6 " 7	1.67	.30	.82	1.59	.33	.80	1.55	.34	.78	1.49	.40	.75	1.45	.43	.71
	8 " 10	2.32	.24	.75	2.27	.27	.74	2.20	.29	.72	2.13	.32	.73	2.12	.38	.72

Proportions for 3000 lb. per sq. in. Concrete

Based on 28-day compressive strength of 6x12 in. cylinders.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:1.5	1:1.7	1:2.0	1:2.3	1:2.7
	3 " 4	1:1.2	1:1.4	1:1.7	1:1.9	1:2.3
	6 " 7	**1:0.9**	**1:1.0**	**1:1.2**	**1:1.4**	**1:1.6**
	8 " 10	1:0.5	1:0.6	1:0.7	1:0.8	1:0.9
No. 4 to ¾ in.	½ to 1	1:1.3:2.7	1:1.5:2.6	1:1.7:2.5	1:1.9:2.4	1:2.3:2.1
	3 " 4	1:1.0:2.3	1:1.2:2.2	1:1.4:2.2	1:1.6:2.0	1:1.9:1.8
	6 " 7	**1:0.7:1.7**	**1:0.8:1.7**	**1:0.9:1.7**	**1:1.1:1.6**	**1:1.3:1.4**
	8 " 10	1:0.3:1.0	1:0.4:1.0	1:0.5:1.0	1:0.5:1.0	1:0.6:0.9
No. 4 to 1 in.	½ to 1	1:1.2:3.1	1:1.3:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.7
	3 " 4	1:0.9:2.7	1:1.1:2.6	1:1.2:2.6	1:1.4:2.5	1:1.7:2.3
	6 " 7	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:2.0**	**1:0.9:1.9**	**1:1.1:1.8**
	8 " 10	1:0.3:1.2	1:0.3:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2
No. 4 to 1½ in.	½ to 1	1:1.1:3.6	1:1.2:3.5	1:1.5:3.5	1:1.7:3.4	1:2.0:3.2
	3 " 4	1:0.9:3.0	1:1.0:2.9	1:1.2:2.9	1:1.4:2.9	1:1.6:2.7
	6 " 7	**1:0.6:2.2**	**1:0.7:2.2**	**1:0.8:2.2**	**1:0.9:2.2**	**1:1.1:2.1**
	8 " 10	1:0.3:1.4	1:0.3:1.3	1:0.4:1.4	1:0.5:1.4	1:0.5:1.3
No. 4 to 2 in.	½ to 1	1:1.0:4.1	1:1.1:4.1	1:1.2:4.1	1:1.4:4.1	1:1.6:4.0
	3 " 4	1:0.8:3.4	1:0.9:3.4	1:1.0:3.5	1:1.1:3.4	1:1.3:3.4
	6 " 7	**1:0.5:2.6**	**1:0.6:2.6**	**1:0.6:2.7**	**1:0.7:2.6**	**1:0.9:2.6**
	8 " 10	1:0.2:1.6	1:0.3:1.6	1:0.3:1.7	1:0.4:1.7	1:0.4:1.7
⅜ to 1 in.	½ to 1	1:1.4:3.1	1:1.5:3.0	1:1.8:2.9	1:2.1:2.8	1:2.4:2.6
	3 " 4	1:1.1:2.6	1:1.3:2.6	1:1.5:2.5	1:1.7:2.4	1:2.0:2.2
	6 " 7	**1:0.8:2.0**	**1:0.8:2.0**	**1:1.0:1.9**	**1:1.1:1.9**	**1:1.3:1.8**
	8 " 10	1:0.4:1.2	1:0.4:1.2	1:0.5:1.2	1:0.6:1.2	1:0.7:1.1
⅜ to 1½ in.	½ to 1	1:1.4:3.5	1:1.5:3.4	1:1.7:3.4	1:2.0:3.3	1:2.3:3.1
	3 " 4	1:1.1:3.0	1:1.2:2.9	1:1.4:2.9	1:1.6:2.8	1:1.9:2.6
	6 " 7	**1:0.8:2.2**	**1:0.8:2.2**	**1:1.0:2.2**	**1:1.1:2.1**	**1:1.3:2.0**
	8 " 10	1:0.4:1.4	1:0.4:1.4	1:0.5:1.4	1:0.6:1.3	1:0.7:1.3
⅜ to 2 in.	½ to 1	1:1.3:4.0	1:1.4:4.0	1:1.6:4.0	1:1.9:3.9	1:2.1:3.8
	3 " 4	1:1.0:3.4	1:1.2:3.4	1:1.3:3.3	1:1.5:3.3	1:1.7:3.2
	6 " 7	**1:0.7:2.6**	**1:0.8:2.5**	**1:0.9:2.6**	**1:1.0:2.6**	**1:1.1:2.5**
	8 " 10	1:0.4:1.6	1:0.4:1.6	1:0.5:1.6	1:0.5:1.6	1:0.6:1.6
¾ to 1½ in.	½ to 1	1:1.6:3.2	1:1.8:3.2	1:2.1:3.2	1:2.4:3.1	1:2.7:2.9
	3 " 4	1:1.3:2.7	1:1.5:2.7	1:1.7:2.7	1:2.0:2.6	1:2.3:2.5
	6 " 7	**1:0.9:2.0**	**1:1.0:2.1**	**1:1.2:2.0**	**1:1.4:2.0**	**1:1.5:1.8**
	8 " 10	1:0.5:1.2	1:0.5:1.3	1:0.6:1.3	1:0.7:1.3	1:0.8:1.2
¾ to 2 in.	½ to 1	1:1.6:3.7	1:1.8:3.7	1:2.0:3.7	1:2.4:3.6	1:2.6:3.5
	3 " 4	1:1.3:3.1	1:1.5:3.1	1:1.6:3.1	1:1.9:3.1	1:2.2:3.0
	6 " 7	**1:0.9:2.4**	**1:1.1:2.4**	**1:1.1:2.4**	**1:1.3:2.4**	**1:1.5:2.3**
	8 " 10	1:0.5:1.5	1:0.5:1.5	1:0.6:1.5	1:0.7:1.5	1:0.8:1.5
¾ to 3 in.	½ to 1	1:1.6:4.2	1:1.8:4.2	1:2.0:4.2	1:2.3:4.1	1:2.6:4.0
	3 " 4	1:1.3:3.5	1:1.5:3.6	1:1.6:3.6	1:1.9:3.6	1:2.1:3.5
	6 " 7	**1:0.9:2.6**	**1:1.0:2.6**	**1:1.1:2.6**	**1:1.3:2.6**	**1:1.4:2.6**
	8 " 10	1:0.5:1.6	1:0.5:1.6	1:0.6:1.7	1:0.7:1.7	1:0.8:1.7

Quantities of Materials for 1 cu. yd. of 3000 lb. per sq. in. Concrete

The volume of cement is expressed in barrels and of aggregates in cubic yards.
F = fine aggregate; C = coarse aggregate.

Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2%; fine aggregate, 10%; coarse aggregate, 5%.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	3.08	.68		2.96	.74		2.65	.78		2.34	.80		2.14	.86	
	3 " 4	3.61	.64		3.31	.69		2.93	.74		2.66	.75		2.37	.81	
	6 " 7	**3.99**	**.53**		**3.79**	**.56**		**3.57**	**.63**		**3.18**	**.66**		**2.93**	**.69**	
	8 " 10	4.77	.35		4.63	.41		4.34	.45		3.93	.47		3.79	.50	
No. 4 to ¾ in.	½ to 1	1.75	.34	.70	1.73	.38	.66	1.69	.42	.63	1.63	.46	.58	1.59	.54	.49
	3 " 4	2.00	.30	.68	1.97	.35	.64	1.93	.40	.63	1.86	.44	.55	1.86	.52	.49
	6 " 7	**2.48**	**.26**	**.62**	**2.46**	**.29**	**.62**	**2.38**	**.32**	**.60**	**2.37**	**.39**	**.56**	**2.35**	**.45**	**.49**
	8 " 10	3.46	.15	.51	3.44	.20	.51	3.38	.25	.50	3.34	.25	.49	3.31	.29	.44
No. 4 to 1 in.	½ to 1	1.68	.30	.77	1.65	.32	.76	1.60	.36	.71	1.55	.41	.66	1.53	.47	.61
	3 " 4	1.88	.25	.75	1.86	.30	.72	1.83	.32	.70	1.78	.37	.66	1.76	.44	.60
	6 " 7	**2.39**	**.21**	**.71**	**2.38**	**.25**	**.70**	**2.32**	**.27**	**.69**	**2.27**	**.30**	**.64**	**2.26**	**.37**	**.60**
	8 " 10	3.32	.15	.59	3.30	.15	.59	3.25	.19	.58	3.21	.24	.57	3.18	.28	.56
No. 4 to 1½ in.	½ to 1	1.58	.23	.84	1.55	.28	.80	1.50	.33	.78	1.46	.37	.73	1.46	.43	.69
	3 " 4	1.80	.24	.80	1.78	.26	.76	1.73	.31	.74	1.68	.35	.72	1.67	.40	.67
	6 " 7	**2.30**	**.20**	**.75**	**2.27**	**.24**	**.74**	**2.21**	**.26**	**.72**	**2.15**	**.29**	**.70**	**2.12**	**.35**	**.66**
	8 " 10	3.19	.14	.66	3.17	.14	.61	3.09	.18	.64	3.04	.22	.63	3.02	.22	.58
No. 4 to 2 in.	½ to 1	1.50	.22	.91	1.49	.24	.90	1.43	.25	.87	1.38	.29	.84	1.38	.33	.82
	3 " 4	1.73	.20	.87	1.71	.23	.86	1.65	.24	.85	1.60	.26	.81	1.60	.31	.80
	6 " 7	**2.18**	**.16**	**.84**	**2.14**	**.19**	**.82**	**2.06**	**.18**	**.82**	**2.01**	**.21**	**.77**	**2.01**	**.27**	**.77**
	8 " 10	3.12	.09	.74	3.09	.14	.73	3.04	.14	.76	2.94	.17	.74	2.94	.17	.74
⅜ to 1 in.	½ to 1	1.69	.35	.77	1.65	.37	.73	1.60	.43	.69	1.54	.48	.64	1.51	.54	.58
	3 " 4	1.91	.31	.73	1.88	.36	.72	1.82	.40	.67	1.78	.45	.63	1.73	.51	.56
	6 " 7	**2.40**	**.28**	**.71**	**2.36**	**.28**	**.70**	**2.31**	**.34**	**.65**	**2.26**	**.37**	**.64**	**2.19**	**.42**	**.58**
	8 " 10	3.23	.19	.57	3.21	.19	.57	3.15	.23	.56	3.00	.27	.53	2.93	.30	.48
⅜ to 1½ in.	½ to 1	1.57	.32	.81	1.55	.34	.78	1.50	.38	.75	1.45	.43	.71	1.43	.49	.66
	3 " 4	1.81	.30	.81	1.78	.32	.76	1.73	.36	.74	1.68	.40	.70	1.63	.46	.63
	6 " 7	**2.30**	**.20**	**.75**	**2.26**	**.27**	**.74**	**2.20**	**.33**	**.72**	**2.15**	**.35**	**.67**	**2.08**	**.35**	**.62**
	8 " 10	2.97	.18	.61	2.94	.17	.61	2.88	.21	.60	2.87	.26	.60	2.78	.30	.55
⅜ to 2 in.	½ to 1	1.49	.29	.88	1.48	.32	.88	1.42	.34	.84	1.36	.38	.77	1.34	.42	.75
	3 " 4	1.73	.26	.87	1.70	.30	.86	1.63	.31	.80	1.58	.35	.77	1.55	.39	.73
	6 " 7	**2.18**	**.23**	**.84**	**2.12**	**.25**	**.79**	**2.05**	**.27**	**.79**	**2.01**	**.30**	**.77**	**1.93**	**.31**	**.72**
	8 " 10	2.98	.18	.71	2.99	.18	.71	2.90	.21	.69	2.93	.22	.69	2.84	.25	.67
¾ to 1½ in.	½ to 1	1.55	.37	.73	1.52	.40	.72	1.48	.46	.70	1.41	.50	.65	1.38	.55	.59
	3 " 4	1.79	.34	.71	1.75	.39	.70	1.71	.43	.68	1.63	.48	.63	1.59	.54	.59
	6 " 7	**2.29**	**.30**	**.68**	**2.24**	**.33**	**.70**	**2.17**	**.39**	**.64**	**2.08**	**.43**	**.62**	**2.03**	**.45**	**.54**
	8 " 10	3.03	.22	.54	3.01	.22	.58	2.93	.26	.56	2.90	.30	.56	2.88	.34	.51
¾ to 2 in.	½ to 1	1.47	.35	.80	1.44	.38	.79	1.40	.41	.77	1.34	.48	.71	1.29	.50	.67
	3 " 4	1.70	.33	.78	1.66	.37	.76	1.62	.38	.74	1.53	.43	.70	1.50	.49	.67
	6 " 7	**2.16**	**.29**	**.77**	**2.08**	**.34**	**.74**	**2.04**	**.33**	**.73**	**1.92**	**.37**	**.68**	**1.90**	**.42**	**.65**
	8 " 10	2.97	.22	.66	2.97	.22	.66	2.81	.25	.62	2.74	.28	.42	2.74	.23	.42
¾ to 3 in.	½ to 1	1.39	.33	.86	1.35	.36	.84	1.30	.38	.81	1.25	.42	.76	1.21	.46	.71
	3 " 4	1.60	.31	.83	1.55	.34	.83	1.52	.36	.81	1.46	.41	.78	1.42	.44	.73
	6 " 7	**2.03**	**.27**	**.78**	**1.98**	**.29**	**.76**	**1.94**	**.32**	**.75**	**1.87**	**.36**	**.72**	**1.83**	**.38**	**.70**
	8 " 10	2.87	.21	.68	2.85	.21	.67	2.75	.24	.69	2.69	.28	.68	2.64	.31	.66

Proportions for 3500 lb. per sq. in. Concrete

Based on 28-day compressive strength of 6x12 in. cylinders.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate	Slump, In.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:1.2	1:1.4	1:1.6	1:1.9	1:2.2
	3 " 4	1:1.0	1:1.1	1:1.3	1:1.5	1:1.8
	6 " 7	**1:0.6**	**1:0.8**	**1:0.9**	**1:1.0**	**1:1.2**
	8 " 10	1:0.3	1:0.4	1:0.4	1:0.5	1:0.6
No. 4 to ¾ in.	½ to 1	1:1.0:2.2	1:1.1:2.2	1:1.3:2.1	1:1.5:2.0	1:1.8:1.8
	3 " 4	1:0.8:1.9	1:0.9:1.9	1:1.0:1.8	1:1.2:1.7	1:1.4:1.5
	6 " 7	**1:0.5:1.3**	**1:0.6:1.4**	**1:0.6:1.3**	**1:0.8:1.3**	**1:0.9:1.2**
	8 " 10	1:0.2:0.7	1:0.2:0.7	1:0.3:0.7	1:0.3:0.7	1:0.4:0.6
No. 4 to 1 in.	½ to 1	1:0.9:2.6	1:1.0:2.6	1:1.2:2.5	1:1.4:2.4	1:1.6:2.3
	3 " 4	1:0.7:2.2	1:0.8:2.2	1:0.9:2.2	1:1.1:2.1	1:1.3:2.0
	6 " 7	**1:0.4:1.5**	**1:0.5:1.5**	**1:0.6:1.5**	**1:0.6:1.5**	**1:0.8:1.4**
	8 " 10	1:0.2:0.8	1:0.2:0.8	1:0.2:0.8	1:0.3:0.8	1:0.3:0.8
No. 4 to 1½ in.	½ to 1	1:0.9:2.9	1:1.0:2.9	1:1.1:2.9	1:1.3:2.8	1:1.5:2.7
	3 " 4	1:0.7:2.5	1:0.8:2.4	1:0.9:2.4	1:1.0:2.4	1:1.2:2.3
	6 " 7	**1:0.4:1.8**	**1:0.5:1.7**	**1:0.5:1.8**	**1:0.6:1.7**	**1:0.7:1.7**
	8 " 10	1:0.2:0.9	1:0.2:0.9	1:0.2:0.9	1:0.2:0.9	1:0.3:0.9
No. 4 to 2 in.	½ to 1	1:0.7:3.3	1:0.8:3.3	1:0.9:3.4	1:1.0:3.3	1:1.2:3.3
	3 " 4	1:0.6:2.8	1:0.6:2.8	1:0.7:2.8	1:0.8:2.8	1:1.0:2.8
	6 " 7	**1:0.3:2.0**	**1:0.4:2.0**	**1:0.4:2.0**	**1:0.5:2.0**	**1:0.6:2.0**
	8 " 10	1:0.1:1.0	1:0.1:1.0	1:0.2:1.0	1:0.2:1.0	1:0.2:1.0
⅜ to 1 in.	½ to 1	1:1.1:2.5	1:1.2:2.5	1:1.4:2.5	1:1.6:2.3	1:1.8:2.2
	3 " 4	1:0.8:2.1	1:0.9:2.1	1:1.1:2.1	1:1.3:2.0	1:1.5:1.9
	6 " 7	**1:0.5:1.5**	**1:0.6:1.5**	**1:0.7:1.5**	**1:0.8:1.4**	**1:0.9:1.4**
	8 " 10	1:0.2:0.8	1:0.2:0.8	1:0.3:0.8	1:0.3:0.8	1:0.4:0.7
⅜ to 1½ in.	½ to 1	1:1.0:2.8	1:1.2:2.8	1:1.3:2.8	1:1.6:2.7	1:1.8:2.6
	3 " 4	1:0.8:2.4	1:0.9:2.4	1:1.1:2.4	1:1.2:2.3	1:1.5:2.3
	6 " 7	**1:0.5:1.7**	**1:0.6:1.7**	**1:0.7:1.7**	**1:0.8:1.7**	**1:0.9:1.6**
	8 " 10	1:0.2:0.8	1:0.2:0.8	1:0.3:0.8	1:0.3:0.8	1:0.4:0.8
⅜ to 2 in.	½ to 1	1:1.0:3.2	1:1.1:3.2	1:1.2:3.2	1:1.4:3.2	1:1.6:3.1
	3 " 4	1:0.8:2.7	1:0.8:2.7	1:1.0:2.7	1:1.1:2.7	1:1.3:2.7
	6 " 7	**1:0.5:1.9**	**1:0.5:1.9**	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:1.9**
	8 " 10	1:0.2:0.9	1:0.2:1.0	1:0.2:1.0	1:0.3:1.0	1:0.3:1.0
¾ to 1½ in.	½ to 1	1:1.3:2.6	1:1.4:2.7	1:1.6:2.6	1:1.9:2.6	1:2.2:2.4
	3 " 4	1:1.0:2.2	1:1.2:2.3	1:1.3:2.2	1:1.5:2.2	1:1.8:2.1
	6 " 7	**1:0.7:1.6**	**1:0.7:1.6**	**1:0.9:1.6**	**1:1.0:1.6**	**1:1.2:1.6**
	8 " 10	1:0.3:0.8	1:0.3:0.8	1:0.4:0.8	1:0.4:0.8	1:0.5:0.8
¾ to 2 in.	½ to 1	1:1.2:3.0	1:1.4:3.1	1:1.6:3.1	1:1.8:3.1	1:2.1:3.0
	3 " 4	1:1.0:2.5	1:1.1:2.6	1:1.2:2.6	1:1.5:2.6	1:1.7:2.5
	6 " 7	**1:0.6:1.8**	**1:0.7:1.8**	**1:0.8:1.9**	**1:0.9:1.9**	**1:1.1:1.9**
	8 " 10	1:0.3:0.9	1:0.3:0.9	1:0.3:0.9	1:0.4:0.9	1:0.5:0.9
¾ to 3 in.	½ to 1	1:1.2:3.4	1:1.3:3.4	1:1.5:3.4	1:1.7:3.3	1:2.0:3.3
	3 " 4	1:1.0:2.8	1:1.1:2.8	1:1.2:2.8	1:1.4:2.8	1:1.6:2.8
	6 " 7	**1:0.6:2.0**	**1:0.7:2.0**	**1:0.8:2.0**	**1:0.9:2.0**	**1:1.0:2.0**
	8 " 10	1:0.3:1.0	1:0.3:1.0	1:0.3:1.0	1:0.4:1.0	1:0.4:1.0

Quantities of Materials for 1 cu. yd. of 3500 lb. per sq. in. Concrete

The volume of cement is expressed in barrels and of aggregates in cubic yards. F = fine aggregate; C = coarse aggregate.

Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2%; fine aggregate, 10%; coarse aggregate, 5%.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes: 0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-3/8 in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	3.58	.64		3.38	.70		3.11	.74		2.71	.76		2.48	.81	
	3 " 4	3.90	.58		3.83	.62		3.51	.68		3.13	.70		2.81	.75	
	6 " 7	4.82	.43		4.34	.52		4.12	.55		3.79	.56		3.46	.61	
	8 " 10				5.00	.30		4.95	.29		4.48	.33		4.37	.30	
No. 4 to ¾ in..	½ to 1	2.08	.31	.68	2.06	.34	.67	2.01	.39	.63	1.91	.42	.57	1.92	.51	.51
	3 " 4	2.38	.28	.67	2.36	.31	.66	2.52	.37	.67	2.25	.40	.57	2.22	.46	.49
	6 " 7	3.08	.23	.59	3.02	.27	.63	2.96	.26	.57	2.88	.34	.56	2.83	.38	.50
	8 " 10	4.02	.12	.42	3.96	.12	.41	3.89	.17	.40	3.83	.17	.40	3.79	.22	.34
No. 4 to 1 in...	½ to 1	1.95	.26	.75	1.93	.29	.74	1.90	.34	.70	1.84	.38	.65	1.84	.43	.63
	3 " 4	2.27	.24	.74	2.25	.27	.73	2.18	.29	.71	2.15	.35	.67	2.10	.40	.62
	6 " 7	2.93	.17	.65	2.89	.21	.64	2.79	.25	.62	2.74	.24	.61	2.67	.32	.55
	8 " 10	3.88	.11	.46	3.82	.11	.45	3.79	.11	.45	3.68	.16	.44	3.67	.16	.43
No. 4 to 1½ in.	½ to 1	1.85	.25	.79	1.85	.27	.79	1.80	.29	.77	1.70	.33	.70	1.73	.38	.69
	3 " 4	2.14	.22	.79	2.11	.25	.75	2.05	.27	.73	1.97	.29	.70	1.98	.35	.67
	6 " 7	2.76	.22	.74	2.70	.20	.68	2.59	.19	.69	2.58	.23	.65	2.58	.27	.65
	8 " 10	3.79	.11	.50	3.69	.11	.49	3.67	.11	.49	3.72	.11	.50	3.80	.17	.51
No. 4 to 2 in...	½ to 1	1.79	.19	.87	1.77	.21	.86	1.71	.23	.86	1.68	.25	.87	1.65	.29	.81
	3 " 4	2.04	.18	.84	2.00	.18	.83	1.95	.20	.81	1.92	.23	.80	1.91	.28	.79
	6 " 7	2.62	.12	.78	2.60	.15	.77	2.52	.15	.75	2.50	.19	.74	2.50	.22	.74
	8 " 10	3.81	.06	.56	3.75	.06	.56	3.72	.11	.55	3.68	.11	.54	3.76	.11	.56
⅜ to 1 in......	½ to 1	2.02	.33	.75	1.94	.34	.72	1.88	.39	.69	1.85	.44	.63	1.79	.48	.58
	3 " 4	2.28	.27	.71	2.24	.30	.70	2.18	.35	.68	2.14	.41	.63	2.05	.45	.58
	6 " 7	2.86	.21	.64	2.84	.25	.63	2.76	.29	.61	2.74	.32	.57	2.66	.35	.55
	8 " 10	3.88	.11	.46	3.82	.11	.45	3.79	.17	.45	3.68	.16	.44	3.67	.22	.38
⅜ to 1½ in....	½ to 1	1.88	.28	.78	1.85	.33	.77	1.79	.34	.74	1.74	.41	.70	1.69	.45	.65
	3 " 4	2.16	.26	.77	2.10	.28	.75	2.04	.33	.73	1.98	.35	.67	1.93	.43	.66
	6 " 7	2.72	.20	.68	2.66	.24	.67	2.59	.27	.65	2.56	.30	.64	2.52	.34	.60
	8 " 10	3.79	.11	.45	3.69	.11	.44	3.67	.16	.43	3.40	.15	.40	3.31	.20	.39
⅜ to 2 in......	½ to 1	1.78	.26	.84	1.75	.28	.83	1.69	.30	.80	1.63	.36	.77	1.59	.38	.73
	3 " 4	2.03	.24	.81	1.98	.23	.79	1.93	.29	.77	1.91	.31	.76	1.84	.35	.73
	6 " 7	2.58	.19	.73	2.54	.19	.71	2.49	.22	.74	2.47	.26	.73	2.40	.28	.68
	8 " 10	3.80	.11	.51	3.73	.11	.55	3.64	.11	.54	3.68	.16	.54	3.56	.16	.53
¾ to 1½ in....	½ to 1	1.84	.35	.71	1.82	.38	.73	1.77	.42	.68	1.68	.47	.65	1.65	.54	.59
	3 " 4	2.13	.32	.69	2.09	.37	.71	2.02	.39	.66	1.85	.41	.60	1.89	.50	.59
	6 " 7	2.68	.28	.64	2.63	.27	.62	2.56	.34	.61	2.49	.37	.59	2.45	.44	.58
	8 " 10	3.79	.17	.45	3.69	.16	.43	3.67	.22	.43	3.72	.22	.44	3.66	.27	.43
¾ to 2 in......	½ to 1	1.76	.31	.78	1.72	.36	.79	1.67	.40	.77	1.58	.42	.72	1.55	.48	.69
	3 " 4	2.01	.30	.74	1.95	.31	.75	1.92	.34	.74	1.84	.41	.71	1.80	.45	.67
	6 " 7	2.58	.23	.69	2.54	.26	.68	2.48	.29	.70	2.40	.32	.68	2.35	.38	.66
	8 " 10	3.78	.17	.50	3.73	.17	.50	3.63	.16	.48	3.59	.21	.48	3.49	.26	.46
¾ to 3 in......	½ to 1	1.67	.30	.84	1.61	.31	.81	1.57	.35	.79	1.51	.38	.74	1.47	.43	.72
	3 " 4	1.91	.28	.79	1.86	.30	.77	1.93	.34	.80	1.76	.36	.73	1.71	.40	.71
	6 " 7	2.48	.22	.74	2.43	.25	.72	2.37	.28	.70	2.30	.31	.68	2.25	.33	.67
	8 " 10	3.64	.16	.54	3.57	.16	.53	3.52	.16	.52	3.46	.20	.51	3.38	.20	.50

Proportions for 4000 lb. per sq. in. Concrete

Based on 28-day compressive strength of 6x12 in. cylinders.

Proportions are expressed by volume as follows: Portland Cement : Fine Aggregate : Coarse Aggregate.

Thus 1:2.6:4.6 indicates 1 part by volume of portland cement, 2.6 parts by volume of fine aggregate and 4.6 parts by volume of coarse aggregate.

Size of Coarse Aggregate	Slump, In.	Proportions Using Fine Aggregate of Different Sizes				
		0-No. 30	0-No. 16	0-No. 8	0-No. 4	0-⅜ in.
None	½ to 1	1:0.9	1:1.1	1:1.2	1:1.5	1:1.7
	3 " 4	1:0.7	1:0.9	1:1.0	1:1.2	1:1.4
	6 " 7	**1:0.4**	**1:0.5**	**1:0.6**	**1:0.7**	**1:0.7**
	8 " 10	1:0.1	1:0.2	1:0.2	1:0.2	1:0.3
No. 4 to ¾ in.	½ to 1	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8	1:1.2:1.7	1:1.4:1.5
	3 " 4	1:0.6:1.5	1:0.6:1.4	1:0.8:1.5	1:0.9:1.4	1:1.1:1.3
	6 " 7	**1:0.3:0.9**	**1:0.4:1.0**	**1:0.4:0.9**	**1:0.5:0.9**	**1:0.6:0.9**
	8 " 10	1:0.1:0.3	1:0.1:0.3	1:0.1:0.3	1:0.1:0.3	1:0.2:0.3
No. 4 to 1 in.	½ to 1	1:0.7:2.1	1:0.8:2.1	1:0.9:2.1	1:1.0:2.0	1:1.2:1.9
	3 " 4	1:0.5:1.7	1:0.6:1.6	1:0.7:1.7	1:0.8:1.7	1:0.9:1.6
	6 " 7	**1:0.3:1.1**	**1:0.3:1.1**	**1:0.4:1.1**	**1:0.4:1.1**	**1:0.5:1.1**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4
No. 4 to 1½ in.	½ to 1	1:0.6:2.4	1:0.7:2.4	1:0.8:2.4	1:1.0:2.3	1:1.1:2.2
	3 " 4	1:0.5:2.0	1:0.5:1.9	1:0.6:2.0	1:0.7:1.9	1:0.9:1.9
	6 " 7	**1:0.3:1.2**	**1:0.3:1.2**	**1:0.3:1.2**	**1:0.4:1.2**	**1:0.4:1.2**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4
No. 4 to 2 in.	½ to 1	1:0.5:2.7	1:0.6:2.7	1:0.7:2.7	1:0.8:2.7	1:0.9:2.8
	3 " 4	1:0.4:2.2	1:0.4:2.2	1:0.5:2.3	1:0.6:2.3	1:0.7:2.3
	6 " 7	**1:0.2:1.4**	**1:0.2:1.4**	**1:0.3:1.4**	**1:0.3:1.5**	**1:0.3:1.4**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.5	1:0.1:0.5	1:0.1:0.5
⅜ to 1 in.	½ to 1	1:0.8:2.1	1:0.9:2.0	1:1.0:2.0	1:1.2:1.9	1:1.4:1.8
	3 " 4	1:0.6:1.7	1:0.7:1.7	1:0.8:1.6	1:0.9:1.6	1:1.1:1.5
	6 " 7	**1:0.3:1.1**	**1:0.4:1.1**	**1:0.4:1.0**	**1:0.5:1.0**	**1:0.6:1.0**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4
⅜ to 1½ in.	½ to 1	1:0.8:2.3	1:0.9:2.3	1:1.0:2.3	1:1.2:2.3	1:1.4:2.2
	3 " 4	1:0.6:1.9	1:0.7:1.9	1:0.8:1.9	1:0.9:1.9	1:1.1:1.8
	6 " 7	**1:0.3:1.2**	**1:0.4:1.2**	**1:0.4:1.2**	**1:0.5:1.2**	**1:0.6:1.2**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4
⅜ to 2 in.	½ to 1	1:0.7:2.6	1:0.8:2.6	1:0.9:2.6	1:1.0:2.6	1:1.2:2.6
	3 " 4	1:0.6:2.1	1:0.6:2.2	1:0.7:2.2	1:0.8:2.2	1:1.0:2.2
	6 " 7	**1:0.3:1.4**	**1:0.3:1.4**	**1:0.4:1.4**	**1:0.4:1.4**	**1:0.5:1.4**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.1:0.5	1:0.1:0.4	1:0.1:0.5
¾ to 1½ in.	½ to 1	1:1.0:2.2	1:1.1:2.2	1:1.3:2.2	1:1.5:2.1	1:1.7:2.0
	3 " 4	1:0.8:1.8	1:0.9:1.8	1:1.0:1.8	1:1.2:1.8	1:1.3:1.7
	6 " 7	**1:0.4:1.1**	**1:0.5:1.1**	**1:0.6:1.2**	**1:0.7:1.1**	**1:0.8:1.1**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4	1:0.2:0.4	1:0.2:0.4
¾ to 2 in.	½ to 1	1:0.9:2.5	1:1.0:2.5	1:1.2:2.5	1:1.4:2.5	1:1.6:2.5
	3 " 4	1:0.7:2.0	1:0.8:2.1	1:0.9:2.1	1:1.1:2.1	1:1.3:2.1
	6 " 7	**1:0.4:1.3**	**1:0.5:1.3**	**1:0.5:1.4**	**1:0.6:1.4**	**1:0.7:1.3**
	8 " 10	1:0.1:0.4	1:0.1:0.4	1:0.2:0.4	1:0.2:0.4	1:0.2:0.4
¾ to 3 in.	½ to 1	1:0.9:2.7	1:1.0:2.7	1:1.2:2.8	1:1.3:2.7	1:1.5:2.7
	3 " 4	1:0.7:2.2	1:0.8:2.3	1:0.9:2.3	1:1.0:2.3	1:1.2:2.2
	6 " 7	**1:0.4:1.4**	**1:0.4:1.4**	**1:0.5:1.5**	**1:0.6:1.5**	**1:0.7:1.5**
	8 " 10	1:0.1:0.5	1:0.1:0.5	1:0.1:0.5	1:0.2:0.5	1:0.2:0.5

Quantities of Materials for 1 cu. yd. of 4000 lb. per sq. in. Concrete

The volume of cement is expressed in barrels and of aggregates in cubic yards. F = fine aggregate; C = coarse aggregate.

Quantities are net, no allowance being made for waste; for average conditions, the following additions are suggested: Cement, 2%; fine aggregate, 10%; coarse aggregate, 5%.

Size of Coarse Aggregate	Slump, in.	Proportions Using Fine Aggregate of Different Sizes														
		0-No. 30			0-No. 16			0-No. 8			0-No. 4			0-⅜ in.		
		Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.	Cement	Aggregate F.	Aggregate C.
None	½ to 1	4.21	.56		3.91	.65		3.75	.79		3.19	.71		2.96	.75	
	3 " 4	4.64	.48		4.25	.57		4.03	.60		3.57	.64		3.27	.68	
	6 " 7	**5.05**	**.30**		**5.21**	**.39**		**4.89**	**.44**		**4.36**	**.45**		**4.41**	**.46**	
	8 " 10													4.78	.21	
No. 4 to ¾ in.	½ to 1	2.46	.29	.65	2.44	.32	.65	2.39	.35	.64	2.33	.41	.59	2.30	.48	.51
	3 " 4	2.86	.25	.64	2.80	.25	.58	2.74	.32	.61	2.64	.35	.55	2.61	.42	.50
	6 " 7	**3.68**	**.16**	**.49**	**3.67**	**.22**	**.54**	**3.62**	**.21**	**.48**	**3.56**	**.26**	**.48**	**3.54**	**.23**	**.34**
	8 " 10	4.79	.06	.23	4.79	.07	.23	4.77	.08	.23	4.76	.10	.23	4.74	.11	.22
No. 4 to 1 in.	½ to 1	2.36	.24	.73	2.32	.27	.72	2.27	.30	.71	2.21	.33	.65	2.18	.39	.61
	3 " 4	2.71	.20	.68	2.65	.24	.63	2.58	.27	.65	2.56	.30	.64	2.54	.34	.60
	6 " 7	**3.59**	**.16**	**.58**	**3.58**	**.16**	**.58**	**3.51**	**.21**	**.57**	**3.46**	**.20**	**.56**	**3.48**	**.26**	**.57**
	8 " 10	4.79	.05	.25	4.76	.05	.26	4.73	.07	.26	4.70	.08	.26	4.69	.09	.26
No. 4 to 1½ in.	½ to 1	2.25	.20	.80	2.21	.23	.78	2.15	.25	.76	2.03	.30	.69	2.05	.33	.67
	3 " 4	2.56	.19	.76	2.54	.19	.71	2.46	.22	.73	2.43	.25	.68	2.42	.32	.68
	6 " 7	**3.48**	**.15**	**.62**	**3.47**	**.15**	**.62**	**3.39**	**.15**	**.60**	**3.34**	**.20**	**.59**	**3.34**	**.20**	**.59**
	8 " 10	4.69	.04	.28	4.69	.05	.28	4.69	.06	.29	4.67	.07	.29	4.67	.08	.29
No. 4 to 2 in.	½ to 1	2.14	.16	.86	2.10	.19	.84	2.03	.21	.81	2.00	.24	.80	1.91	.26	.79
	3 " 4	2.47	.15	.80	2.45	.15	.80	2.37	.18	.81	2.33	.21	.79	2.31	.24	.78
	6 " 7	**3.36**	**.10**	**.70**	**3.33**	**.10**	**.69**	**3.24**	**.14**	**.67**	**3.19**	**.14**	**.71**	**3.20**	**.14**	**.66**
	8 " 10	4.69	.03	.31	4.68	.03	.30	4.67	.04	.32	4.61	.04	.33	4.54	.05	.33
⅜ to 1 in.	½ to 1	2.36	.29	.73	2.32	.31	.69	2.26	.33	.67	2.22	.39	.62	2.13	.44	.57
	3 " 4	2.65	.24	.67	2.62	.27	.66	2.58	.31	.61	2.54	.34	.60	2.48	.40	.55
	6 " 7	**3.42**	**.15**	**.56**	**3.39**	**.20**	**.55**	**3.33**	**.20**	**.49**	**3.30**	**.24**	**.49**	**3.23**	**.29**	**.48**
	8 " 10	4.79	.06	.26	4.76	.07	.25	4.73	.08	.26	4.70	.10	.25	4.69	.12	.24
⅜ to 1½ in.	½ to 1	2.26	.27	.77	2.20	.29	.75	2.14	.32	.73	2.08	.37	.71	2.00	.41	.65
	3 " 4	2.54	.23	.71	2.51	.26	.71	2.48	.29	.70	2.42	.32	.68	2.36	.38	.63
	6 " 7	**3.24**	**.14**	**.58**	**3.17**	**.19**	**.56**	**3.16**	**.19**	**.56**	**3.10**	**.23**	**.55**	**3.13**	**.28**	**.56**
	8 " 10	4.69	.06	.28	4.69	.07	.28	4.69	.08	.28	4.67	.09	.28	4.67	.11	.28
⅜ to 2 in.	½ to 1	2.14	.22	.82	2.08	.25	.80	2.01	.27	.77	1.98	.29	.76	1.92	.34	.74
	3 " 4	2.46	.22	.76	2.42	.21	.79	2.34	.24	.76	2.31	.27	.75	2.22	.33	.72
	6 " 7	**3.14**	**.14**	**.65**	**3.07**	**.14**	**.64**	**3.02**	**.18**	**.63**	**3.02**	**.18**	**.63**	**2.98**	**.22**	**.62**
	8 " 10	4.69	.05	.30	4.68	.06	.30	4.67	.07	.32	4.61	.08	.31	4.54	.08	.31
¾ to 1½ in.	½ to 1	2.23	.33	.72	2.18	.35	.71	2.12	.41	.69	2.01	.45	.62	1.95	.49	.58
	3 " 4	2.53	.30	.68	2.49	.33	.66	2.44	.36	.65	2.42	.43	.65	2.29	.44	.58
	6 " 7	**3.18**	**.19**	**.52**	**3.12**	**.23**	**.51**	**3.03**	**.27**	**.54**	**2.97**	**.31**	**.48**	**2.98**	**.35**	**.49**
	8 " 10	4.69	.08	.26	4.69	.10	.27	4.69	.11	.28	4.67	.12	.28	4.67	.15	.27
¾ to 2 in.	½ to 1	2.11	.28	.78	2.05	.30	.76	1.99	.35	.74	1.91	.40	.71	1.88	.44	.69
	3 " 4	2.44	.25	.72	2.39	.28	.74	2.34	.31	.73	2.24	.36	.70	2.18	.42	.68
	6 " 7	**3.12**	**.18**	**.60**	**3.11**	**.23**	**.60**	**3.00**	**.22**	**.62**	**2.94**	**.26**	**.61**	**2.90**	**.30**	**.56**
	8 " 10	4.69	.08	.29	4.68	.09	.30	4.67	.10	.30	4.61	.11	.30	4.54	.13	.30
¾ to 3 in.	½ to 1	1.98	.25	.79	1.94	.29	.77	1.90	.34	.79	1.84	.35	.74	1.78	.40	.71
	3 " 4	2.33	.24	.76	2.28	.27	.78	2.21	.30	.75	2.12	.31	.72	2.06	.37	.67
	6 " 7	**3.00**	**.18**	**.62**	**2.97**	**.18**	**.62**	**2.96**	**.22**	**.66**	**2.80**	**.26**	**.64**	**2.77**	**.29**	**.62**
	8 " 10	4.60	.08	.32	4.54	.08	.32	4.49	.09	.32	4.44	.10	.32	4.43	.12	.32

Appendix C

JOINT COMMITTEE ON SPECIFICATIONS FOR CONCRETE PIPE

JOB TUTHILL, *Chairman;* A. F. ROBINSON, *Joint Committee.*

The Joint Concrete Culvert Pipe Committee was formed to prepare Standard Specifications for Concrete Pipe for railroad and highway use and is composed of representatives of the following societies:

American Society for Testing Materials:

Chairman, Anson Marston, Dean, Engineering Department, Iowa State College, Ames, Iowa.

A. E. Phillips, Sanitary Engineer Washington, D. C.

American Society Civil Engineers:

T. L. D. Hadwen, Masonry Engineer, C. M. & St. P. Ry., Chicago, Ill.

Geo. H. Tinker, Bridge Engineer, N. Y. C. & St. L. Ry., Cleveland, Ohio

American Concrete Institute:

A. B. Cohen, Consulting Engineer, New York City.

B. S. Pease, Engineer, American Steel & Wire Company, Chicago, Illinois.

American Concrete Pipe Association:

C. F. Buente, Manager, Concrete Products Company, Pittsburgh, Pa.

Paul Kircher, Western Manager, Massey Concrete Products Company, Chicago, Ill.

American Association of State Highway Officials:

Prof. T. R. Agg, Iowa State College, Ames, Iowa.

J. N. Mackall, Chairman, Maryland State Road Commission, Baltimore, Md.

Bureau of Public Roads, U. S. Department of Agriculture:

Thos. H. MacDonald, Chief of Bureau.

A. T. Goldbeck, Engineer of Tests.

American Railway Engineering Association:

A. F. Robinson, Bridge Engineer, Atchison, Topeka & Santa Fe Railway.

Job Tuthill, Assistant Chief Engineer, Pere Marquette Railway.

The first meeting of the Committee was held at Atlantic City, June 27, 1919, when Mr. H. T. Shelly, then representing the American Society for Testing Materials, was elected Chairman and the following sub-committees were appointed:

No. 1—Classification and Loading Requirements.
No. 2—Design.
No. 3—Methods and Requirements of Tests.
No. 4—Workmanship and Installation.

The representation at this meeting was but one member from each association and it was decided to ask that a second representative be appointed. This was subsequently done, bringing the membership to its present numbers.

Professor Agg advised the meeting that the Iowa State College would extend its experimental work in its investigation of pressures of earth on pipes to include larger sizes and greater height of fills, conforming to conditions of railroad and highway work and that the information obtained would be available to the Committee for determining the loading that should be considered in designing concrete pipe.

Several meetings of sub-committees and two of the general committee have been held since and more or less preliminary work done awaiting more definite information as to the actual pressures coming on pipes from fills. Last spring Mr. Shelly resigned and Dean Marston was appointed in his stead as representative for the American Society for Testing Materials and elected by the Committee as its chairman.

The investigation at the Engineering Experiment Station of the Iowa State College to determine the pressures of earth on pipes under conditions similar to those of railroad and highway work has been in progress and two experiments completed. The details of these and the results obtained will be published in a Bulletin at an early date by the Engineering Experiment Station. A pipe 42 inches in diameter was used and the embankment carried to a height of twenty feet. In a general way the results indicate considerably greater pressures than have heretofore been assumed or considered probable and that the pressure increases in proportion to the increase in the height of the fill above the pipe. The Engineering Experiment Station intends to continue this investigation, as it is not felt that the results so far obtained are sufficient to afford an authoritative answer to the question, and that considerable more experimental work is necessary.

The information gained has been made available for the immediate use of the Committee and will be a valuable help in its work.

Appendix D

OUTLINE OF WORK FOR THE ENSUING YEAR

C. C. Westfall, *Chairman;* R. Armour, T. L. Condron, Richard L. Humphrey, *Sub-Committee.*

The following outline of work is recommended for next year's work:

1. Study the Manual and submit proposed revisions thereof.
2. Continue representation on Joint Committee on Standard Specifications for Concrete and Reinforced Concrete and report progress and recommendations thereon.
3. Continue representation on Joint Committee on Specifications for Concrete Pipe and report progress and recommendations thereon.
4. Study and report on factors causing deterioration of concrete structures.
5. Report on distribution of loads and impacts through ballast and embankments as affecting the design of masonry structures.
6. Study and report on the developments in the art of making concrete.
7. Recommend a carefully considered outline of work for the ensuing year.

Appendix E

COMMENTS ON TENTATIVE REPORT OF THE JOINT COMMITTEE ON CONCRETE AND REINFORCED CONCRETE

Samuel T. Wagner, Chief Engineer, Philadelphia & Reading Railway

The Joint Committee on Standard Specifications for Concrete and Reinforced Concrete are to be congratulated upon the promptness with which they have presented their first progress report. When the efforts of the original Joint Committee on Concrete and Reinforced Concrete are considered, which was in 1904 and finished its labors in 1916, the promptness of the existing Committee is especially commendable.

The difficulty in the preparation of the present report it is believed lies in the fact that it is not as easy to prepare a specification as it is to set down items of recommended practice on which a specification could be based. In a general way what is now presented has very many commendable features and if all of the conclusions are accepted as facts, it will be comparatively easy for an Engineer to prepare a specification for any particular kind of work. It is believed that the present report bears the earmarks which characterized so many of the reports of the American Society for Testing Materials at the 1921 convention; that is, that the majority of the conclusions are based on research work rather than on the personal experience and opinions of the members of the Joint Committee.

The following are a few of the points which appear to deserve some comment. No attempt has been made to cover the section devoted to Design.

(III) Quality of Concrete.—A distinct innovation is introduced in this Section, in that the Engineer is to specify the strengths required for the concrete in the various parts of the work based either upon preliminary test or upon the view given in Table IV. From the theoretical and scientific standpoint, this is, of course, ideal, as it recognizes the various uses to which the method is applied. It contemplates much more testing and of a much more elaborate kind than has ever been used in general practice and particularly upon work of moderate size and how it will work out practically is an open question. The theoretical idea is sound.

The proposed use of the slump test for determining consistency is a decided step forward in the proposed specification. It is an easy test to make on the work and after the proper amount of slump is determined for any piece of work, it is a simple matter to test the consistency frequently, and thus keep check on it. This is a very difficult operation without such a test. The use of mortar tests of a fine aggregate, using either briquettes, cylinders or prisms, compared with similar tests of Ottawa sand is believed to be the only adequate manner of determining its quality and is sure to exclude from important work many grades of fine aggregate which should never be used and which could not otherwise be detected.

(V) Proportioning and Mixing.—Many engineers will have difficulty in determining which of the methods given shall be used. It is to be hoped that in final report the number of these methods may be reduced.

The requirement of devices for automatically measuring the amount of water is to be commended, as it is one of the essentials of uniform workmanship. Many of the seeming refinements such as this may appear to be uncalled for, but when consideration is given to the fact that the type of material called for is made on the ground largely by unskilled labor and frequently under inadequate supervision, it must be recognized that more care must be exercised in the essentials which are known to be responsible for the quality of the finished product. Among these is also the requirement of the minimum time that each batch shall be in the mixer.

(VI) Depositing Concrete.—There seems to be no good reason why the distances should be specified between stones in the rubble cyclopean concrete. If the stones are imbedded in the concrete after it has been placed, it is impossible to know how far apart they are, and even if they do touch, there is probably sufficient concrete between them to answer every purpose. It is entirely proper to specify that the stone should be kept away from the surface of the concrete.

(IX) Waterproofing and Protection Treatment.—The paragraph under Waterproofing is distinctly disappointing. For certain classes of plain or reinforced concrete structures the necessity of providing some method of protecting them from the action of the water is of great importance and deserves more definite treatment than has been given. It is believed that the general statements made in this paragraph are in accord with good practice. The details of how the work is to be done are woefully lacking and it is to be hoped that the Committee will fully cover the matter in their final report.

The requirements under Section X—Surface Finish—are a distinct advantage over any specification of a general character to be published up to the present time, and the practice is generally good. While it seems perfectly proper to mention sand blast finish under "Decorative Finishes" as one which could be considered, it is the opinion of the writer from experience that it is neither satisfactory nor advisable on account of the difficulty of obtaining uniform results.

C. C. Williams, Professor of Civil Engineering, University of Kansas

In the list of Definitions, I would define "cement paste" as "a paste formed by mixing hydraulic cement and water"; then I would define "concrete" as "an artificial conglomerate stone formed by cementing aggregates together with cement paste. The term is also applied to the material in the plastic state during fabrication."

I do not believe the term "brackets" should be used at the bottom of page 11, in the definition of "buttressed retaining wall," nor in the definition of "counterforted retaining wall," and would suggest the word "buttresses" in the former case and "counterforts" in the second.

Under quality of concrete, page 15, I would suggest the four distinct classes of concrete be made:

Class A, for highly reinforced concrete requiring 2,000 pounds per square inch or more at twenty-eight days.

Class B, for ordinary reinforced construction and first class plain concrete.

Class C, plain concrete retaining walls, dams, etc.

Class D, concrete for bearing walls and other structures where very light load is required.

On page 16, paragraph 11, I do not believe the specification of fine aggregate in terms of strength of 1:3 standard sand mortar is entirely adequate.

Certain tests made under my direction showed a high strength for fine aggregates which proved unsatisfactory for concrete (see Engineering News-Record, May 22, 1919).

Also I would make a classification of fine aggregate of three classes as follows:

Class A aggregate shall consist of quartz sand containing not more than 5 per cent clay and shall be free from organic impurities. It shall be graded in size, all particles passing a one-fourth-inch screen and not more than 30 per cent shall pass a 50-mesh screen. Stone screenings of a durable hard mineral having the same properties may be used.

Class B aggregate shall consist of sand composed of quartz and other minerals of fairly hard and durable texture or a calcareous sand having properties similar to those of Class A. The clay contents shall not exceed 10 per cent and organic matter shall not exceed that giving a color with the standard test darker than a medium brown; quartz sand 75 per cent of which passes a 20-mesh screen with not more than 5 per cent clay and free from organic matter may be used; stone screenings of a durable character and containing not more than 7 per cent clay, with not more than 50 per cent passing a 50-mesh screen may be used.

Class C fine aggregate shall consist of sand or screenings containing clay not to exceed 15 per cent and not more than 60 per cent passing a 50-mesh screen.

I would also suggest a corresponding classification of coarse aggregate.

On page 21, paragraph 31, one and a half minutes seems to me to be needlessly long for the mixing of concrete.

The above classifications are intended to be suggestive rather than carefully defined. My idea is that the specifications should recognize that all construction cannot be first class and should provide for inferior grades of work as well as for first grade.

F. Auryansen, Bridge Engineer, Long Island Railroad

In the Preface, the Committee calls attention to the fact that the specification is developed particularly on the basis of reinforced concrete work in buildings and this has led to some definitions and statements which are perhaps a little inconsistent with requirements for bridge work. I assume, however, that the representatives of the A.R.E.A. have given due consideration to this phase of the subject, and that inconsistencies will be remedied in subsequent editions.

In the definitions of "Aggregate," neither slag nor light weight aggregate are included.

A "column" is defined as a vertical compression member, whereas in bridge or foundation work a compression member which would be designed as a column, might not necessarily be a vertical member. Similarly, in a cantilever retaining wall, the upright stem might not be vertical nor the supporting base strictly horizontal.

"Dead loads" are defined as weight of structures plus fixed loads and forces. Perhaps "fixed loads and constant forces" would be a better expression, the contrast being with live loading which varies in amount, duration and position.

Engineer.—The engineer in responsible charge of design and construction—add the words "or his duly authorized representative."

Laitance.—Add to the definition, the condition under which it is formed, namely, "when excess mixing water is used."

Membrane Waterproofing.—Substitute the following definition—"A bituminous coating of two or more layers reinforced by intermediate fabric, felt or similar strengthening material; applied to structures to prevent contact of moisture." It should be noted that the function of the fabric is not only to reinforce, but it also assists in securing a composite coating having more pitch than could generally be applied by mopping directly upon the surface of a previously placed layer. In this respect, the open mesh fabrics are superior to the felts;. they are also much stronger.

Mention should be made of other kinds of waterproofing, such as mastic, or brick laid in hot tar or bitumen.

Pedestal or Pier.—A vertical compression member whose height does not exceed three times its least horizontal dimension.

Reinforced Footing is not mentioned. It might be defined as a member supporting a column, in which the projection from the face of the column is greater than one-half the depth, or is of such spread as to require reinforcement.

(III) Quantity of Concrete.—Section 3, line 3, would substitute the following: Compressive strength at 28 days as determined by "specific" tests of the materials.

(IV) Materials.—F. Water.—19. Does not mention salt, but leaves it to be implied in "other deleterious substance."

G. Metal Reinforcement.—Table 1, Page 18—Omits square bars of ⅜", ⅝", ¾" and ⅞" size. We have found in our work that ⅝" square bars go very nicely in $\frac{13}{16}$" punched holes.

25. Cast-iron would not be used in bridge work.

(V) Proportioning and Mixing Concrete.—28. Proportions—under the alternate methods, bottom of page 20, nothing is said in regard to the proper amount of water to be used in mixing.

(C) Mixing.—Should take account of the temperature limitations which should be imposed. I suggest that Section 41 be subdivided, and the references to suitable mixing temperatures be inserted following Section 33.

(VII) Forms.—53. Top of page 25 insert the word "anchored" to read—"they shall be properly anchored, braced or tied together so as to maintain position and shape." Forms for retaining wall with inclined back have been known to rise under the component of hydro-static pressure of the concrete producing an upward reaction.

54. Next to last sentence might read—"Forms shall be set to line and grade and so constructed and fastened as to produce correct lines."

56. Possibly special mention should be made of the treatment of metal forms to prevent concrete adhering to same.

58. Second line revised to read—"nor shall the principal shores be removed," etc.

(VIII) Details of Construction.—A. Metal Reinforcement.—59. Change second sentence to read "Reinforcement to carry calculated stress, if appreciably reduced in section, shall be rejected."

(C) Joints.—69. The common practice of using metal members for bonding, such as projecting rods, pieces of old rail, etc., is not covered unless by implication from Section 65.

73. Construction joints in long "structures." Construction joints made crosswise of a "structure" 100 ft. or more in length, etc. Many bridges are much longer than ordinary buildings.

74. Second sentence on page 28 implies that the joints are horizontal I would suggest that this be revised to read—"Exposed expansion joints formed between two distinct concrete members shall be of approved design and filled with elastic joint filler of approved quality, or made waterproof by other suitable means."

75. Change heading to read—"Expansion Joints in Long 'Structures'."

77. Seems to assume horizontal joint which may not always be the case. A different style of treatment is required for horizontal and for inclined joints. I would suggest that the definition be extended to provide for reinforcement in the case of fixed joints, which would hold the abutting sections of the structure in their proper relation.

(IX) Waterproofing and Protective Treatment.—78. Amend second sentence to read—"Particular attention should be given to secure the best kind and quality of workmanship."

80. As above mentioned, does not allow for the use of mastic or brick in hot pitch. Nothing is said regarding protection of the waterproofing membrane, which is vital to its integrity. I would refer the Committee to the Principles for Detail Design of Flashing, Drainage, Reinforcement and Protection for Waterproofing Purposes, found on page 395, Bulletin 232.

(C) Concrete in Sea Water.—85. Protection—Revise second sentence to read—"Metal chairs, supports, ties or other members shall not extend to within 2″ of the surface of the concrete." Add to the section a provision that no sharp corners shall be allowed.

(X) Surface Finish.—93. Revise second sentence to read—Care shall be taken to avoid an excess of mixing water in the concrete, and to drain off or to otherwise promptly remove any such excess water that comes to the surface after the concrete is deposited.

(XI) Design.—On page 33—Section 105-D—Various ratios are given for the moduli of elasticity of steel and 28 day concrete, but frequently in railroad work it is found necessary to put loads upon structures inside of 28 days. What should the corresponding ratios be in such cases, that is, how will the age of the concrete affect the ratio, defined in paragraph 107 as "n"? It would be desirable to have the values of Sec. 105, etc., indicated by graphs where possible.

Section 115 would not seem to apply to a continuous width of floor of bridge supported at intervals by beams; in such a case what would be the unsupported length of flange? Isolated T-beams mentioned in Section 119, might have a portion or all of their length unsupported laterally, but I cannot conceive of an entire floor, supported by beams, which would be lacking in lateral support for these beams.

Page 58—following "J"—it would be desirable to have another article dealing with arches. Perhaps the Committee will cover this in a later edition.

Pages 61 to 64—Table 4 gives minute proportions expressed by volume; as the text indicates that proportioning by weight may be allowed, how are the figures given in table 4 to be of service in obtaining the correct proportions when the weight method is employed in proportioning?

The Joint Committee is to be highly commended for establishing the standard notation given in Appendix 1—page 65, etc., as much confusion in the future will thereby be avoided.

A. F. Ganier, Assistant Engineer Design, Nashville, Chattanooga & St. Louis Railway

No. 7—Stone screenings is included among the materials for the fine aggregate. The results we have had hereabouts with certain grades of limestone are such that I think the specification should eliminate limestones which will not stand the weather.

No. 79—Eliminates the use of integral water-proofing compounds. This is a rather sweeping decision, and I can find no reason for such elimination in the literature I have read. A small amount of hydrated lime (10 per cent.) has been shown by competent authorities to actually increase the strength of concrete, aside from its quality of rendering it more water-proof. The membrane method recommended is too expensive for many classes of work.

No. 82. I think that the reference to the "surface coating" should be amplified to say that "this coating shall be such that it will enter and fill the pores, thus reducing the porosity of the concrete."

No. 95—The second paragraph of this section does not clearly provide for the removal, from the surface, of all dust and other foreign matter which would affect the bond.

Page No. 32—That portion of the pamphlet dealing with the mathematical design has been arranged even more clearly than heretofore and fuller discussion than formerly has been given relative to the use of the formulae. With the small amount of time available I do not feel competent to take issue as to the use, or rather choice, of certain formulae which are recommended in the report.

The method of giving working stresses in concrete is such that great latitude is allowed, i.e., concrete having an ultimate compressive strength of 1,500 to 3,000 lb. per sq. in. is allowed a working stress of 0.4 f^1c or from 600 to 1,200 lb. per sq. in. In competitive work there has been a strong tendency to stretch and even go beyond all recommendations. The stresses allowed are all right provided the Committee's recommendations as to proportions, choice of aggregates and methods of mixing are also carried out. This is rarely complied with, in this section at least, and the actual concrete put into the job is too often of the particular brand preferred by the foreman. I think the report should lay more stress on the necessity of field practice, conforming to its recommendations, and that engineering inspection should be counted in and recognized as a proper element of the cost of good concrete.

C. L. Wilson, Assistant Engineer, Bridge, Nashville, Chattanooga & St. Louis Railway

On page 19, paragraph 27, last sentence, and on page 81, paragraph 30, regarding the water measuring devices. I have never seen a contractor's equipment, that has been in service for any length of time and that carries such devices, to be in working order. Good concrete has been made by men experienced in mixing without an automatic water measuring device. At the same time, I realize that a certain amount of water added to the different mixes gives the maximum strength for that mix. For this reason the amount of water added should be measured as accurately as possible. This can be done by buckets, if the amount is previously determined by the engineer in charge.

Page 21, paragraphs 31 and 32, regarding time of mixing. It is true, that in hand mixing the batch is usually turned six times after the water is added. If this is necessary, then the time (1½ minutes) required for machine mixing, after all material is in the machine, is longer than necessary and the yardage guaranteed by the manufacturer cannot be made in some makes of machines.

Different types and sizes of mixers require different times to make a homogeneous batch and an experienced man at the machine can tell when the mixing is complete.

I believe paragraph 31 should be revised, leaving out the time element, and reading the same as the last sentence of paragraph 32.

On page 26, paragraph 63. Plans usually show the position of splices. Rods are ordered and called for to allow the proper lap to develop the bond. Position of other splices that become necessary on account of construction features should be decided by the engineer in charge. The first sentence to be left unchanged.

Page 28, paragraph 79. This paragraph precludes the use of hydrated lime and coloring pigments, while paragraph 104, page 32, allows the use of colored pigments.

The results obtained from the added lime can be secured by the addition of a small percentage of cement and a careful grading of the aggregate.

C. H. Johnson, Assistant Engineer, Nashville, Chattanooga & St. Louis Railway

The specifications cover not only the construction of concrete structures, but also their design, and I think it would be well to separate the specifications into two parts: one covering construction and the other covering design, instead of attempting to cover both in one set of specifications. As an example, I call your attention to page 26, where clauses 60, 61 and a part of 62 are applicable to construction, whereas, the latter part of 62, all of 63 and 64 refer to design only.

The clauses under the head of "Mixing" on page 21 are too stringent. It is entirely possible to secure first-class concrete with mixer using no charging hopper, no water measuring device or no locking device. In fact it has been my experience that charging hopper and water measuring devices are a nuisance and I avoid their use wherever possible.

The specifications requiring concrete to be turned in the mixer 1½ minutes after the mixer is completely charged should be revised to read "Concrete shall be turned in the mixer a sufficient length of time to produce a batch that is homogeneous in appearance and color." This time will vary greatly with different types of mixers. We have one mixer where the material has to be turned one minute and a half or two minutes. We have another mixer where as good or better concrete may be made in three-fourths of a minute.

I note that in mixing by hand the specifications require that the material shall be turned at least six times after water is added. This is entirely inconsistent with the clause providing for holding material in the mixer 1½ minutes.

On page 28, under "Waterproofing," clause 79, "Integral compounds shall not be used." This would seem to exclude the use of hydrated lime, which we have found to be very satisfactory.

Page 29, under "Oilproofing," clause 82, closes with the sentence "The treatment to be applied shall be approved by the engineer." I believe a treatment, or some treatment, should be recommended by the Committee, since these specifications are to be used as a guide to engineers in preparing specifications to fit local conditions.

REPORT OF COMMITTEE V—ON TRACK

W. P. Wiltsee, *Chairman;*
J. V. Neubert, *Vice-Chairman;*
L. B. Allen,
V. Angerer,
J. B. Baker,
R. A. Baldwin,
C. W. Breed,
G. H. Bremner,
H. G. Clark,
E. A. Hadley,
G. W. Hegel,
E. T. Howson,
T. T. Irving,
H. A. Lloyd,
J. deN. Macomb,
W. S. McFetridge,
F. H. McGuigan, Jr.,
J. B. Myers,
F. L. Nicholson,
J. H. Reinholdt,
G. J. Slibeck,
J. B. Strong,
J. R. Watt,

Committee.

To the American Railway Engineering Association:

Report is respectfully submitted on the following subjects:

(1) Revision of Manual

Proposed changes in the Manual, Items I, II and III, are given in Appendix A.

(2) Typical Plans of Turnouts, Crossovers, Slip Switches, Double Crossovers and Railroad Crossings, and Detail Plans for Such Work

In Appendix B the Committee reports on this subject, and its recommendations are given under Conclusions.

(3) Plans and Specifications for Track Tools

In Appendix C the Committee reports on this subject, and its recommendations are given under Conclusions.

(4) Specifications and Piece Work Schedules for Contracting Maintenance Work

In Appendix D the Committee submits "Specifications and Unit Track Work Schedules for Contracting Maintenance Work," and its recommendations are given under Conclusions.

(5) Plans and Specifications for Switch Stands, Switch Lamps and Switch Locks

In Appendix E the Committee reports on this subject, and its recommendations are given under Conclusions.

(6) Gages and Flangeways for Curved Crossings

In Appendix F the Committee submits an explanatory report on Tables No. 1 and No. 2 recommended for adoption and publication in the Manual (Appendix A, Item III).

(7) (a) Tests of Tie Plates Subject to Brine Drippings; (b) the Effect of Brine Drippings on Track Appliances

In Appendix G the Committee submits a progress report on this subject.

(8) Reduction of Taper of Tread of Wheel to 1 in 38, and Canting the Rail Inward

In Appendix H the Committee submits a progress report.

(9) Outline of Work for the Ensuing Year

The Committee's recommendations are given under Recommendations for Future Work.

CONCLUSIONS

1. The Committee recommends that the additions to the Manual as submitted in Appendix A be approved.

2. The Committee recommends certain plans for adoption and others to be received as information. Appendix B also covers progress report on uncompleted work, and reassignment of the subject is requested.

3. The Committee recommends that the plans submitted be adopted and that the subject be reassigned, that the preparation of specifications which could not be completed may be continued.

4. The Committee recommends that the specifications submitted be adopted, and the Committee be authorized to continue its work on this topic.

5. The Committee recommends one plan for adoption and another to be received as information, and submits a list of certain A.R.A. Signal Section plans, which it recommends for endorsement by the Association, and a progress report to be received as information. The Committee recommends that this subject be continued.

6. The tables submitted in Appendix A, Item III, and explanatory report in Appendix F completes the work of this Sub-Committee. The Committee recommends that this subject be discontinued.

7. The Committee recommends that the progress report in Appendix G be received as information and that the subject be reassigned.

8. The Committee recommends that the progress report in Appendix H be accepted as information and that the subject be continued.

Recommendations for Future Work

9. With the exception of Subject No. 6, the Committee recommends that the present assignments be continued, and, in addition, the following new subjects:

(a) Method to be used in determining recommendations for rail renewals.
(b) Curving of rails, recommending limits of curvature to spring in track for various weights of rails, etc.
(c) Results obtained from oiling track fixtures.
(d) The use of guard rails on curves, considering specifications to cover conditions, as: degree of curvature; speed; traffic conditions; grade.

Respectfully submitted,

The Committee on Track,

W. P. Wiltsee, *Chairman*.

Appendix A

(1) STUDY THE MANUAL AND SUBMIT PROPOSED REVISIONS THEREOF

W. P. WILTSEE, *Chairman;*
J. V. NEUBERT,
V. ANGERER,
G. H. BREMNER,
E. A. HADLEY,
G. W. HEGEL,
E. T. HOWSON,
T. T. IRVING,
J. deN. MACOMB,
Sub-Committee.

Item I

The Committee recommends the following Supplement to the Specifications for Switches, Frogs, Crossings and Guard Rails, adopted March, 1921:

SUPPLEMENT TO SPECIFICATIONS FOR SWITCHES, FROGS, CROSSINGS AND GUARD RAILS

Manganese Steel Track Castings

1. GENERAL CONDITIONS.—Castings shall be reasonably smooth and true to pattern in accordance with good foundry practice. Large lumps, sharp fins, sand and chills on the outside of castings shall be removed. The castings shall be free from such blow holes, sand holes, cracks, cold shuts and other defects which would impair their serviceability and as further specified below. Castings must be out of twist and reasonably true, both as to general surface and alinement, and must not show any signs of straining or undue denting produced in the straightening process.

The bottom part of castings which rest on ties shall be reasonably straight and out of twist, and shall be free from lumps or such imperfections as would prevent a good bearing.

2. IMPERFECTIONS.—Tread surfaces within 2½ in. of gage line and side of groove 1 in. down from tread shall be free from physical defects, such as shrinkage cracks, sand holes, blow holes, cold shuts or segregation of metal, unless such defects are so small that they have been practically removed by the finish grinding, and there must be no indication of unsoundness of the metal. Shrinkage cracks, cold shuts or segregation of metal will not be allowed in any part of the tread surfaces. Sand holes, blow holes, and cold shuts in portions of the casting where they will not appreciably weaken the casting, or impair its wearing qualities, will be permitted. Castings must be free from shrinkage cracks running vertically in web members of solid work or horizontally at or near the ends or in corners of junction of projecting members or longitudinally in grooves. Other small shrinkage cracks which do not materially weaken the casting will be acceptable.

The above Supplement, it is felt, would be of material assistance to the inspector on this class of work.

Item II

The Committee recommends that plan No. 252, dated November, 1921, and titled "Details of Lamp Tips for Switch Stands," be adopted, and that Section 12 of "Requisites for Switch Stands, Including Connecting Rods," adopted March, 1921, be revised to refer to this plan, to read:

"12. Lamp tips shall conform to plan No. 252."

It was found there are at present in service lamp tips of a great variety of dimensions, varying in many cases by only a small fraction of an inch, each set of dimensions requiring individual patterns or dies. Hence, as one detail of lamp tip could not be proposed to meet all conditions, a sufficient variety of styles has been illustrated to meet various operating requirements. Detail 61 conforms to A.R.A. Signal Section standard.

Item III

In reference to article "Gage on Curves," adopted, Vol. 11, Part 2, 1910, pp. 942, 954, 955; Vol. 16, 1915, pp. 733, 1145, reading:

"GAGE ON CURVES"

Present

"Curves 8 deg. and under should be standard gage. Gage should be widened ⅛ in. for each 2 deg. or fraction thereof over 8 deg., to a maximum of 4 ft. 9¼ in. for tracks of standard gage. Gage, including widening due to wear, should never exceed 4 ft. 9½ in.

"Where frogs occur on *the inside of* curves, the gage at the frog should be standard or the flangeway of the frog should be widened to compensate for the increased gage."

Proposed

For general conditions in main line tracks, curves 8 deg. and under should be standard gage. Gage should be widened ⅛ in. for each 2 deg. or fraction thereof over 8 deg., to a maximum of 4 ft. 9¼ in. for tracks of standard gage. Gage, including widening due to wear, should never exceed 4 ft. 9½ in.

Where frogs occur on curves, the gage at the frog should be standard or the flangeway of the frog should be widened to compensate for the increased gage.

For the widening of gage and flangeways on curves for the operation of specific locomotives or for special conditions and for curved crossings, refer to Tables No. 1 and No. 2 for "Gages and Flangeways in Curved Track."

The Committee recommends that the following supplementary tables be adopted and published in the Manual:

Table No. 1, dated November, 1921, and entitled

"GAGES AND FLANGEWAYS IN CURVED TRACK"

Table No. 2, dated November, 1921, and entitled

"GAGES AND FLANGEWAYS IN CURVED TRACK—GAGE DIAGRAMS FOR RIGID WHEEL BASE LOCOMOTIVES"

An explanation of these tables is given in Appendix F.

Appendix B

(2) REPORT ON TYPICAL PLANS OF TURNOUTS, CROSS-OVERS, SLIP SWITCHES, DOUBLE CROSSOVERS AND RAILROAD CROSSINGS, AND DETAIL PLANS FOR SUCH WORK

J. V. NEUBERT, *Chairman;*
W. P. WILTSEE,
L. B. ALLEN,
V. ANGERER,
J. B. BAKER,
C. W. BREED,
E. A. HADLEY,
H. A. LLOYD,
J. DEN. MACOMB,
W. S. MCFETRIDGE,
J. B. MYERS,
G. J. SLIBECK,
J. B. STRONG,
Sub-Committee.

The Committee recommends the following plans for adoption:

Bolted Rail Crossings

Plan 701. Three rail design, angles 90° to 50° inclusive.
Plan 702. Two rail design, angles 90° to 50°, inclusive.
Plan 703. Three rail design, angles below 50° to 35°, inclusive.
Plan 704. Two rail design, angles below 50° to 35°, inclusive.
Plan 705. Three rail design, angles below 35° to 25°, inclusive.
Plan 706. Two rail design, angles below 35° to 25°, inclusive.
Plan 707. Single rail design and two rail design with short easer rails, angles below 25° and above 14°15′.
Plan 708. Single rail design and two rail design, angles below 25° and above 14°15′.
Plan 709. Single rail design and two rail design with short easer rails, angles 14°15′ to 8°10′, inclusive.
Plan 710. Single rail design and two rail design, angles 14°15′ to 8°10′, inclusive.

Manganese Steel Insert Crossings

Plan 751. Designs and dimensions of inserts, angles 45° to above 14°15′, Detail "A."
Plan 752. Designs and dimensions of inserts, angles 45° to above 14°15′, Detail "B."
Plan 753. Designs and dimensions of inserts, angles 14°15′ to 8°10′, inclusive.
Plan 754. Three rail design, angles below 45° to 35°, inclusive, Detail "A."
Plan 755. Two rail design, angles below 45° to 35°, inclusive, Detail "A."
Plan 756. Three rail design, angles below 35° to 25°, inclusive, Detail "A."
Plan 757. Two rail design, angles below 35° to 25°, inclusive, Detail "A."
Plan 758. Two rail design with short easer rails, angles below 25° and above 14°15′, Detail "A."
Plan 759. Two rail design, angles below 25° and above 14°15′, Detail "A."
Plan 760. Single rail design with short easer rails, angles below 25° and above 14°15′, Detail "A."
Plan 761. Single rail design, angles below 25° and above 14°15′, Detail "A."
Plan 762. Three rail design, angles below 45° to 35°, inclusive, Detail "B."
Plan 763. Three rail design, angles below 35° to 25°, inclusive, Detail "B."
Plan 764. Two rail design with short easer rails, angles below 35° to 25°, inclusive, Detail "B."
Plan 765. Two rail design with short easer rails, angles below 25° and above 14°15′, Detail "B."

Plan 766. Single rail design with short easer rails, angles below 25° and above 14°15′, Detail "B."
Plan 767. Two rail design, angles 14°15′ to 8°10′, inclusive.
Plan 768. Single rail design, angles 14°15′ to 8°10′, inclusive.

Twelve of the above crossing plans were presented as information in report for annual meeting of March, 1921. These are now resubmitted with such revisions as were found desirable, with additional plans to make the set complete, the plans of Bolted Rail Crossings covering angles from 90 deg. down to and including 8 deg. 10 min., and the plans of Manganese Steel Insert Crossings, angles from 45 deg. down to and including 8 deg. 10 min. These plans are the result of over two years' work and study and comparison with different railroad standards and standard plans of the manufacturers; and, as submitted, have the approval of both your Committee and the Switch and Frog Manufacturers of the Manganese Track Society.

The Committee also recommends that the following plans be received as information only:

Plan 801. No. 8 double slip switch with movable center points with uniform risers.
Plan 802. No. 8 double slip switch with movable center points with graduated risers.
Plan 851. Details of No. 8 double slip switch with movable center points with uniform risers.
Plan 852. Details of No. 8 double slip switch with movable center points with graduated risers.

The Committee invites your criticism, that the plans may be revised if found desirable and resubmitted next year for adoption, with plans for slip switches of other angles.

The above layouts are for the same alinement, the same length of end switch (16′6″) and movable crossing points (10′4″) being shown on both plans. Plan 801 with uniform risers details switch points conforming to Switch Plan 101, the uniform risers being carried throughout under the inside circle rails between the heels of the inside switch points. Plan 802 with graduated risers details switch points conforming to Switch Plan 102.

Special attention is called to the alternates on both layouts, which are considered good practice and which will not make it necessary to change the alinement or any essential details.

Appendix C

(3) SUBMIT FINAL PLANS AND SPECIFICATIONS FOR TRACK TOOLS, COLLABORATING WITH COMMITTEE ON BALLAST

T. T. IRVING, *Chairman;*
W. P. WILTSEE,
J. B. BAKER,
R. A. BALDWIN,
C. W. BREED,
G. W. HEGEL,
F. H. MCGUIGAN, JR.,
F. L. NICHOLSON,
J. R. WATT,
Sub-Committee.

Plans are submitted for the following Track Tools: Pinch Bar, Lining Bar, Claw Bar, Track Wrench, Adze, Rail Fork, Spike Pullers, Track Gage, Rail Tongs, Track Chisel, Clay Pick, Spike Maul, Sledge, Track Level and Track Shovel.

The plans are the result of two years' consideration by the Committee, during which time the important manufacturers of Track Tools have been consulted and the standard plans of a large number of railroads examined. The Committee have not undertaken to furnish plans for Tamping Bar, Tamping Pick, Ballast Fork, etc., as plans for these tools have been prepared by the Committee on "Ballast."

Two types of Claw Bar are submitted, Nos. 1 and 2. Type No. 2 is used more extensively than No. 1. The Committee feel, however, that both types should be submitted.

Two types of Track Levels are shown, type No. 1 having an adjustable arm for measuring elevation for curves. Type No. 2 is what is ordinarily known as the "Stop Level" and very commonly used on American and Canadian railroads.

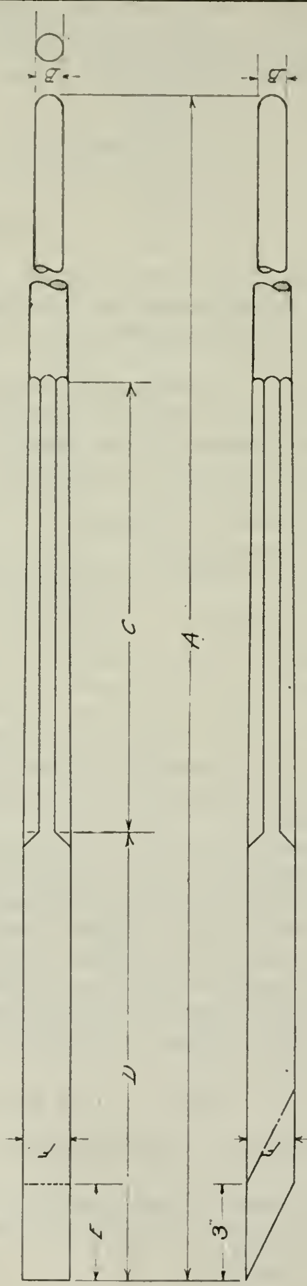
In addition to the ordinary type of Adze, the Committee submit a Pick-Eye Adze. This tool can be used with an ordinary pick handle. The Pick-Eye Adze is coming into somewhat general use and should be considered in standard Track Tools.

Track Wrenches are submitted for Track Bolts of following diameter: ¾", ⅞", 1", 1⅛", 1¼". Bolts up to 1⅛" in diameter are used in ordinary track construction, while bolts of a larger diameter are used in special work such as frogs and diamond crossings. Two lengths of wrenches are recommended as shown in the drawing. The first is used with ordinary open-hearth steel bolts and the second is used with heat-treated or alloy steel bolts. In the design of these wrenches, some consideration was given to the length of wrench necessary to develop the approximate tensile strength of the bolt.

The Rail Tongs are designed to handle rails up to and including 130-lb. sections.

The Committee recommend that the plans submitted be inserted in the Manual.

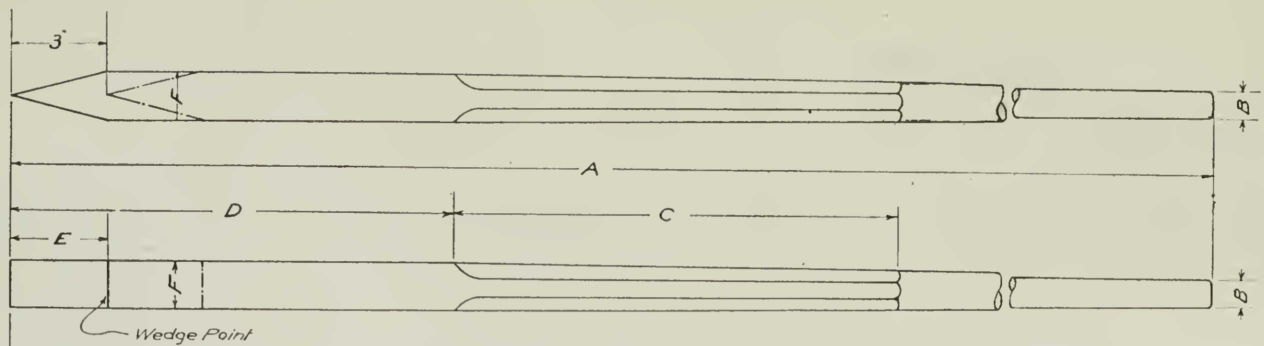
The Committee are not yet ready to submit Specifications for Track Tools and recommend that this subject be continued during the year 1922.

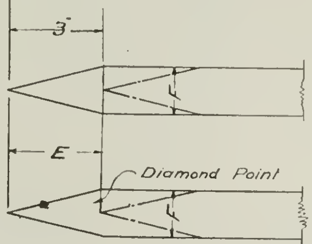


PINCH BAR

Note:
Limit of wear shown thus ———
Name of Manufacturer and year made to be stamped on each tool

WT	18lb	20lb	26lb
A	5'0"	5'3"	5'6"
B	3/4"	3/4"	7/8"
C	13½"	14"	14"
D	13½"	14"	14"
E	3"	3"	3"
F	1¼"	1¼"	1½"

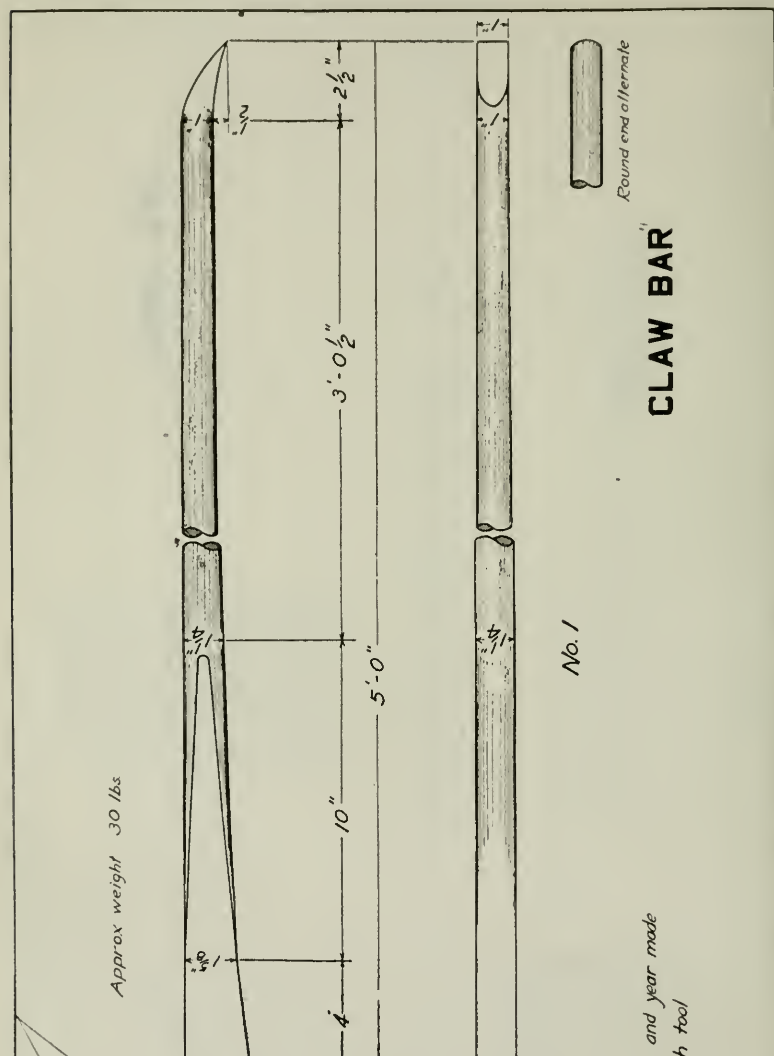


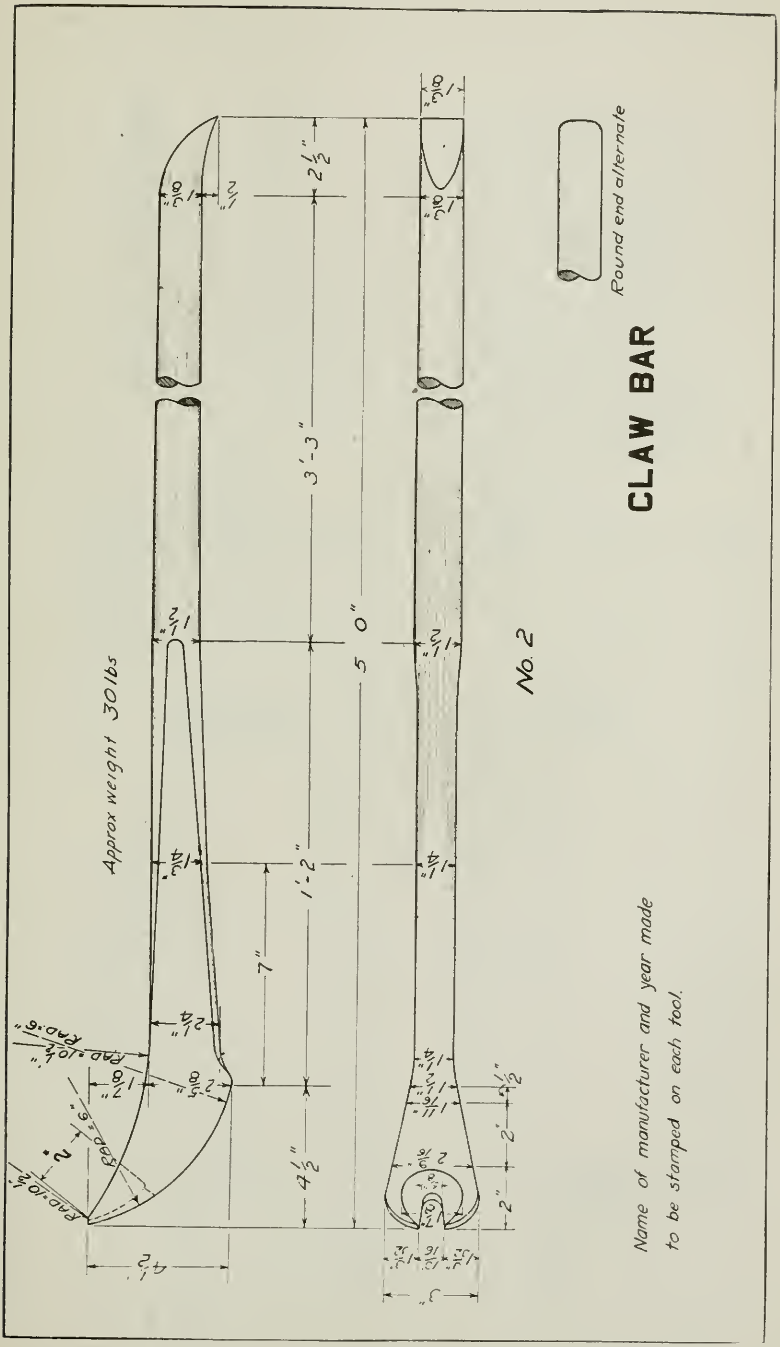


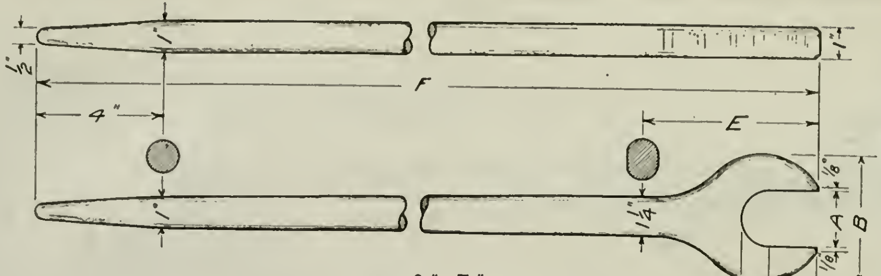
WT.	18 lb	20 lb	26 lb
A	5'0"	5'3"	5'6"
B	3/4"	3/4"	7/8"
C	13 1/2"	14"	14"
D	13 1/2"	14"	14"
E	3"	3"	3"
F	1 1/4"	1 1/4"	1 1/2"

LINING BAR

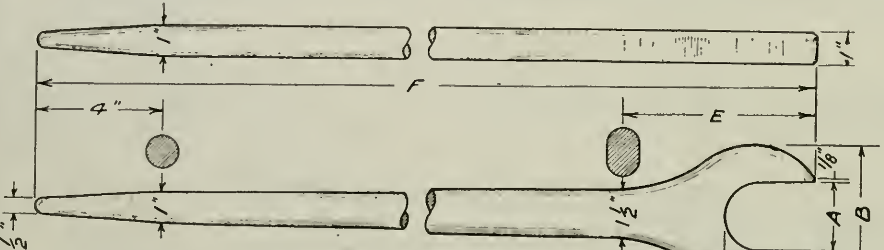
Note:
Limit of wear shown thus —·—·—
Diamond points may be substituted for wedge.
Name of Manufacturer and year made to be stamped on each tool


CLAW BAR
No. 1
Round end alternate
Approx weight 30 lbs.
Name of manufacturer and year made
to be stamped on each tool
5'-0"
3'-0½"
2½"
10"
4"
5⅝"


CLAW BAR
No. 2
Approx weight 30 lbs
Round end alternate
Name of manufacturer and year made
to be stamped on each tool.
5' 0"
3'-3"
1'-2"
7"
$4\frac{1}{2}$"
$2\frac{1}{2}$"



Wrench for 3/4", 7/8" and 1" Bolts
Approx. Wt. 6½ Lbs.

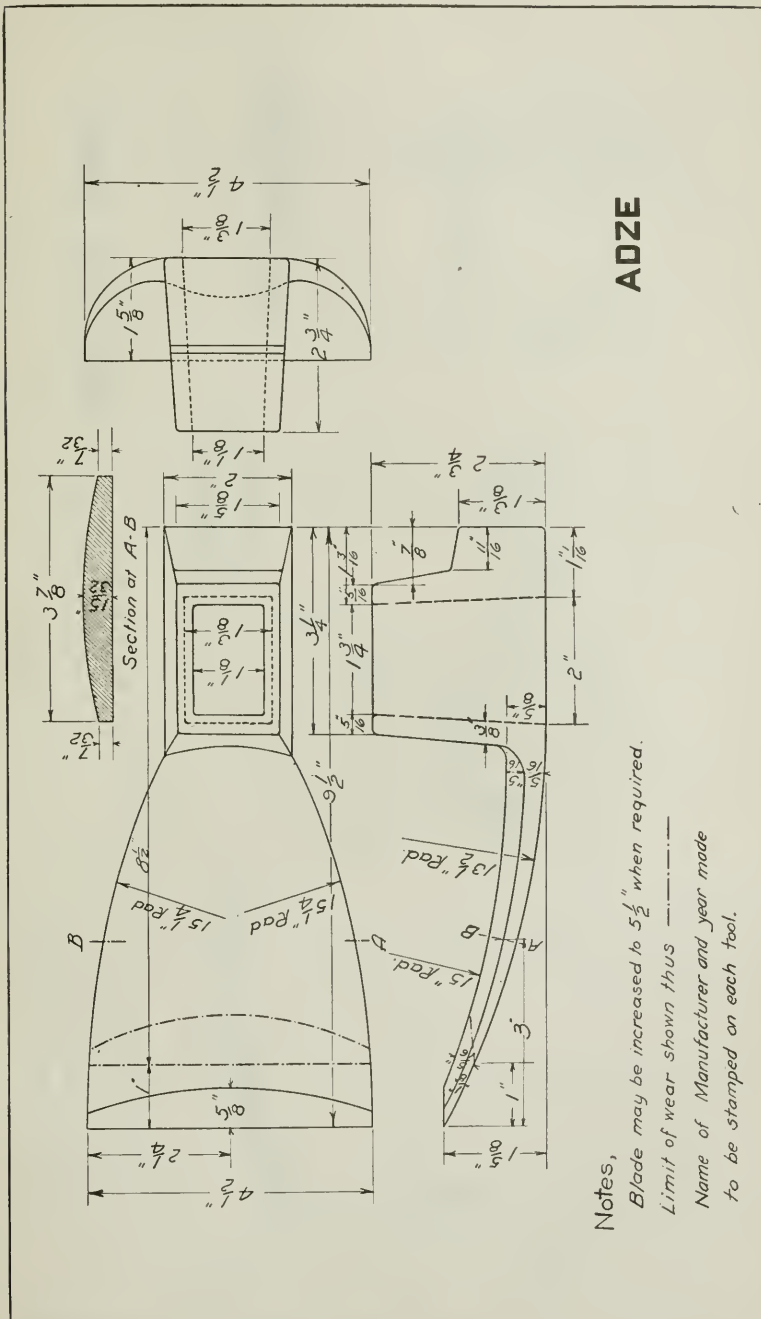


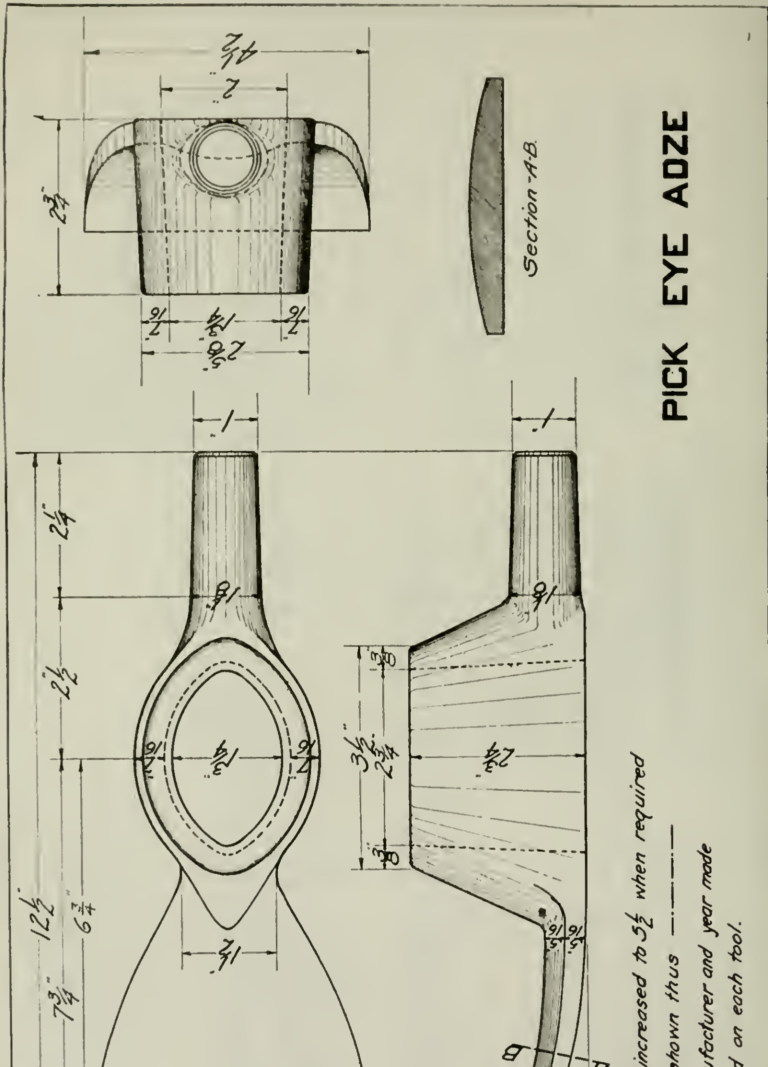
Wrench for 1 1/8" and 1 1/4" bolts
Approx. Wt. 7½ Lbs.

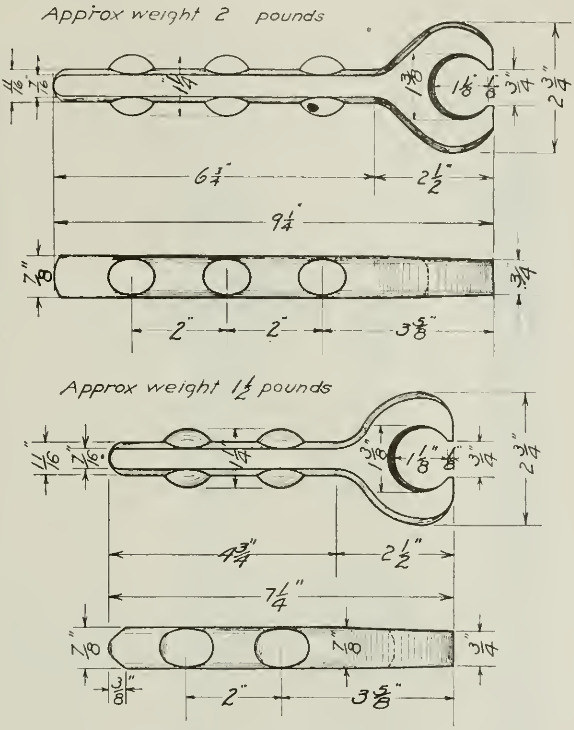
Diam. Bolt	Nut Width Across Flats	Wrench Dimensions A	B	C	D	E	F	F_1
3/4"	1 1/4"	1 3/8"	3 1/2"	1 1/4"	11/16"	4 1/2"	30"	36"
7/8"	1 7/16"	1 9/16"	3 3/4"	1 3/8"	25/32"	5"	30"	42"
1"	1 5/8"	1 3/4"	4"	1 1/2"	7/8"	5 1/2"	30"	42"
1 1/8"	1 13/16"	1 15/16"	4 1/4"	1 5/8"	31/32"	6"	36"	48"
1 1/4"	2"	2 1/8"	4 1/2"	1 3/4"	1 1/16"	6 1/2"	42"	48"

NOTES.-
F = Length for use with open hearth steel bolts
F_1 = Length for use with heat treated or alloy steel bolts
Width of jaw "A" is shown for square nuts
If hexagonal nuts are used, decrease this dimension 1/16"
Name of Manufacturer and year made to be stamped on each tool

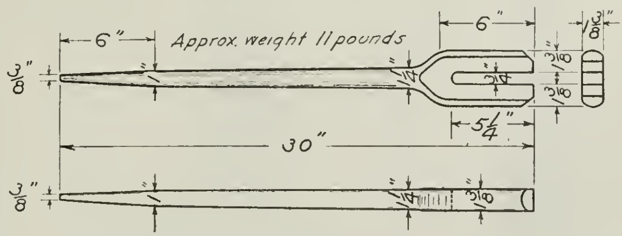
TRACK WRENCHES


ADZE
Section at A-B
Notes,
Blade may be increased to 5½" when required.
Limit of wear shown thus —·—·—
Name of Manufacturer and year made
to be stamped on each tool.


PICK EYE ADZE
Section A-B
Note:
Blade may be increased to 5½ when required
Limit of wear shown thus
Name of Manufacturer and year made
to be stamped on each tool.

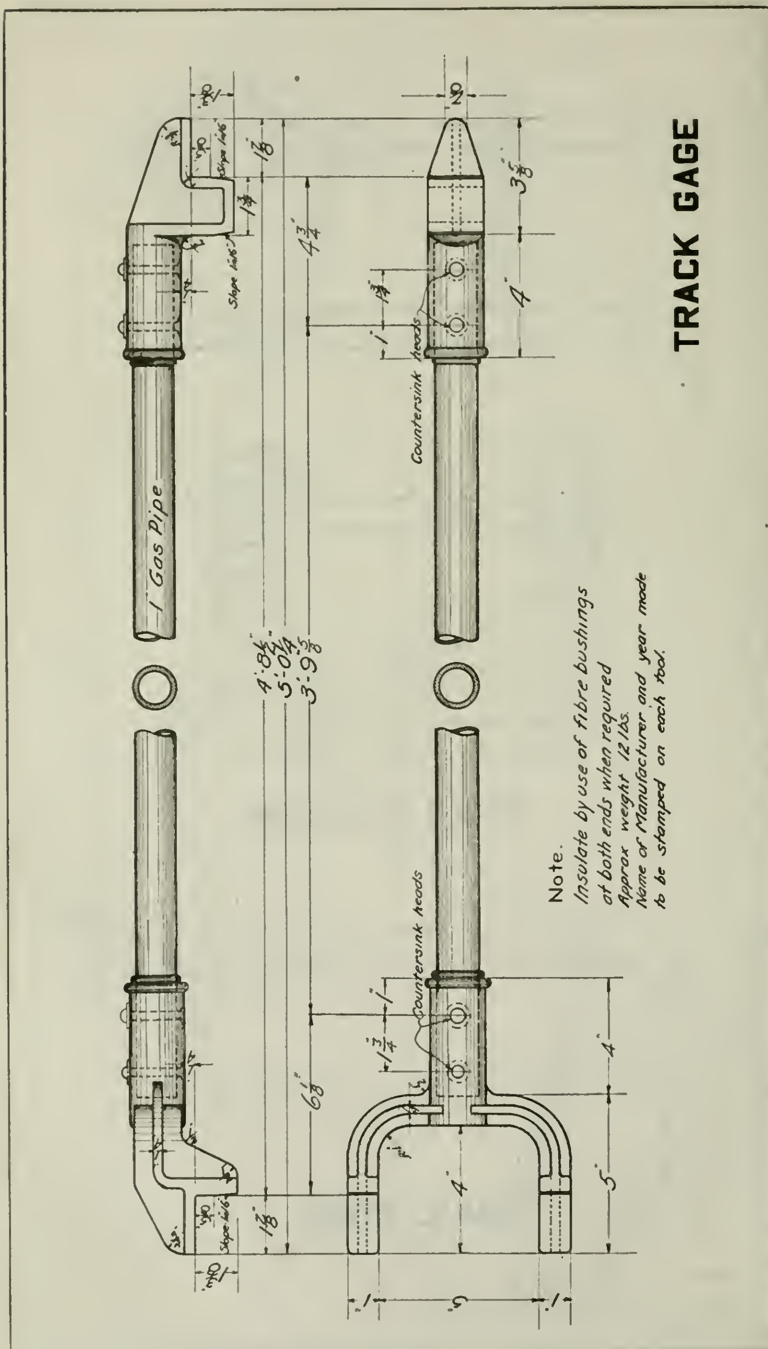


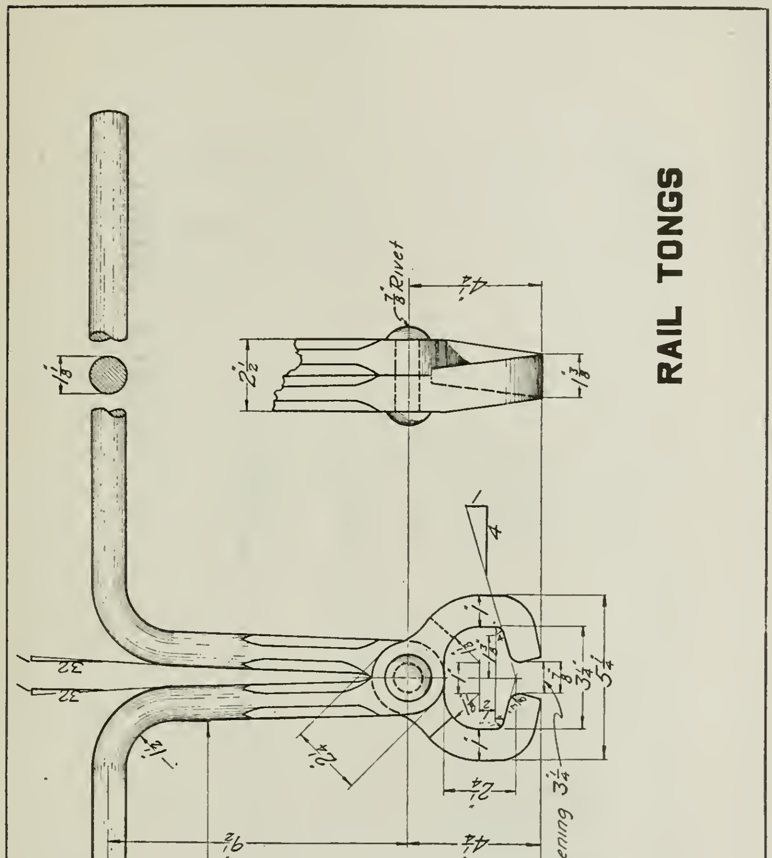
SPIKE PULLERS



RAIL FORK

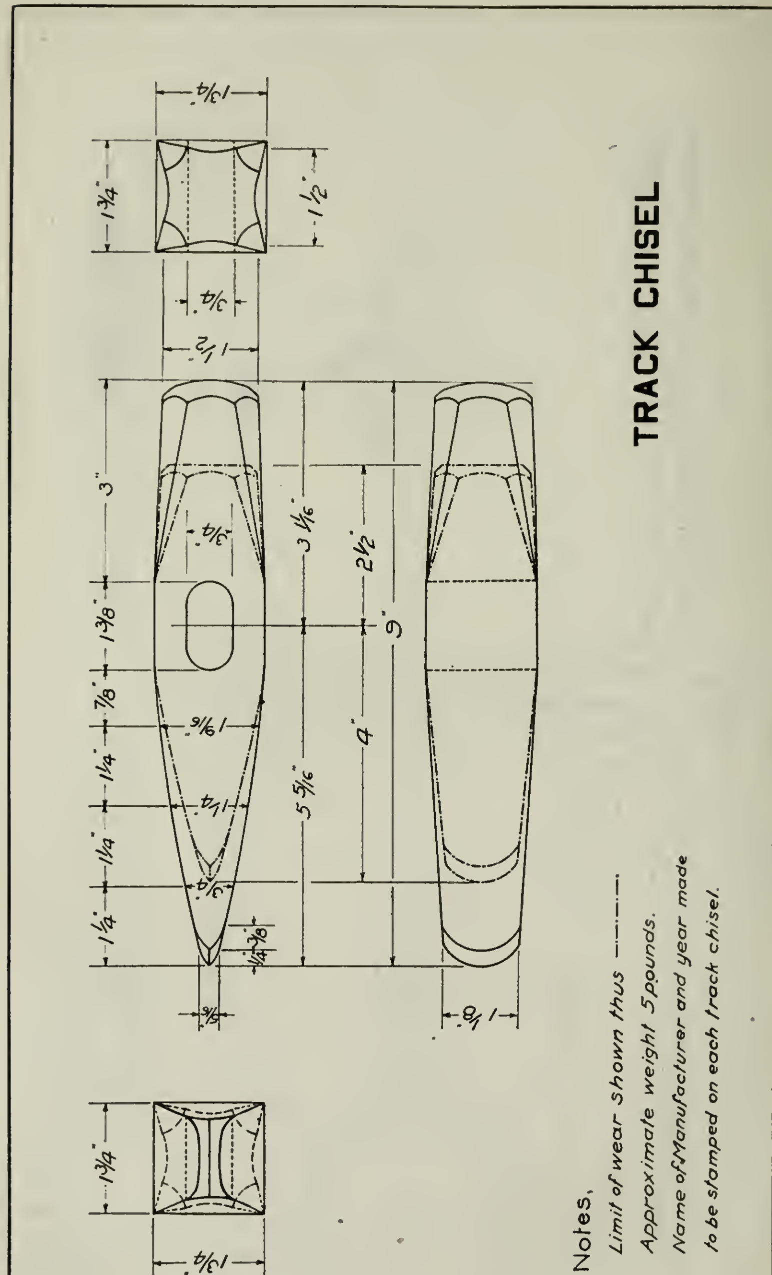
Name of Manufacturer and year made to be stamped on each tool

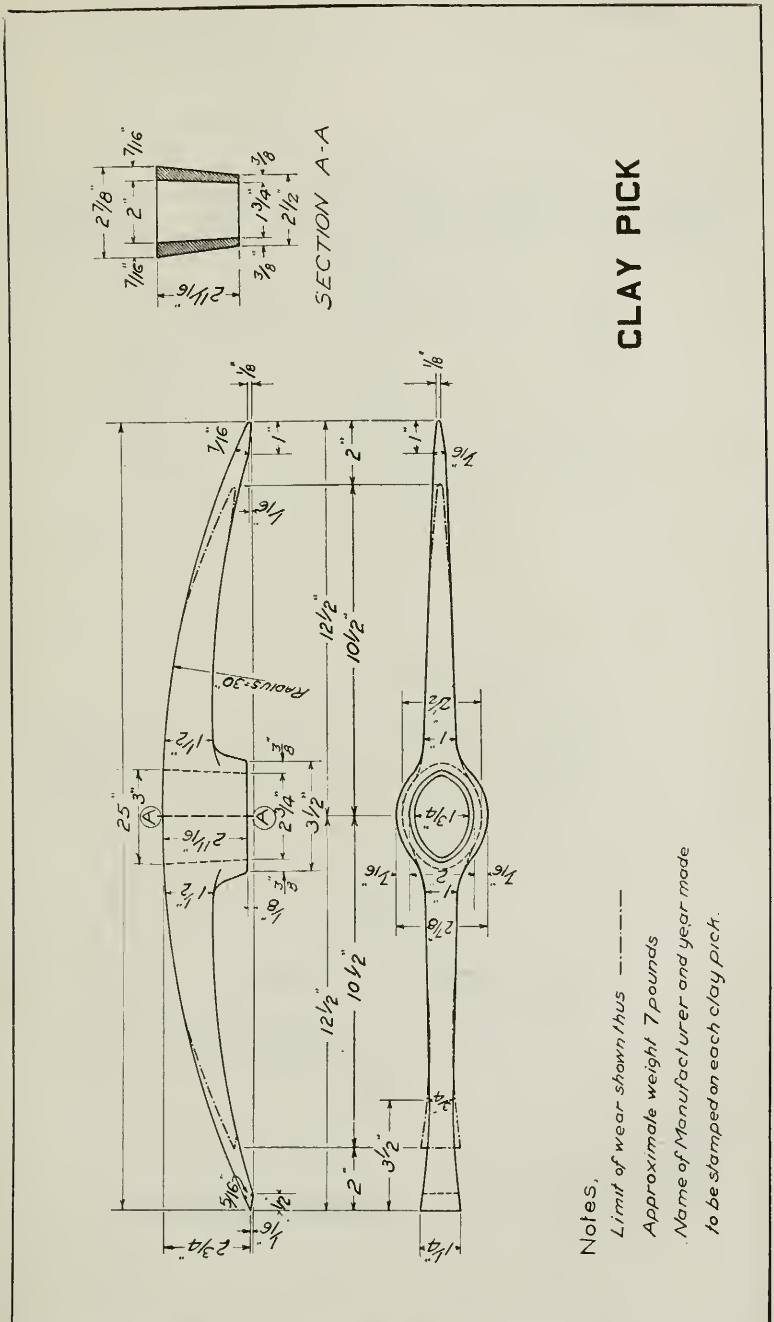

TRACK GAGE
Note.
Insulate by use of fibre bushings
at both ends when required
Approx. weight 12 lbs.
Name of Manufacturer and year made
to be stamped on each tool.
1" Gas Pipe
Countersink heads
Countersink heads
4' 8½"
5' 0¼"
3' 9⅝"
Slope 1in16

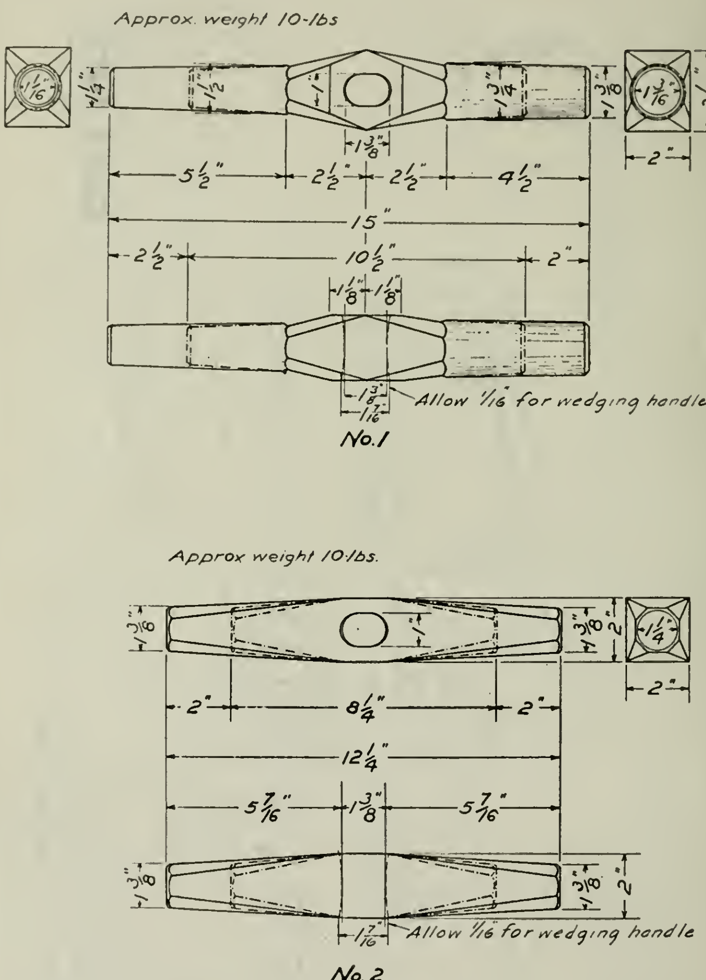


RAIL TONGS

Notes:-
Approx. weight 18 pounds.
Name of Manufacturer and year made to be stamped on each tool.


TRACK CHISEL
Notes,
Limit of wear shown thus —·—·—
Approximate weight 5 pounds.
Name of Manufacturer and year made
to be stamped on each track chisel.
1¾"
1½"
¾"
3"
3 1/16"
2½"
1⅜"
9"
⅞"
1 9/16"
1¼"
4"
5 5/16"
1⅛"
5/16"
¼"
⅜"


SECTION A-A
RADIUS=30"
CLAY PICK
Notes,
Limit of wear shown thus —·—·—
Approximate weight 7 pounds
Name of Manufacturer and year made
to be stamped on each clay pick.

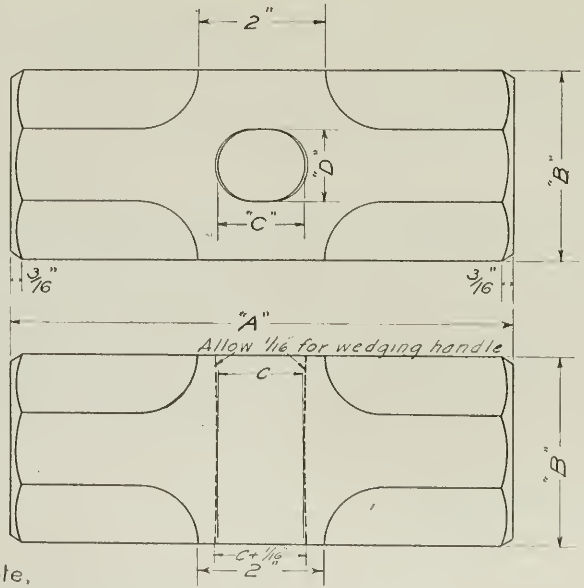


Note:-

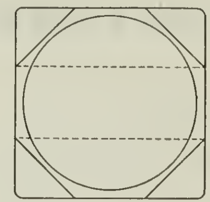
Limit of wear shown thus —·—·—

Name of manufacturer and year made to be stamped on each tool.

SPIKE MAULS

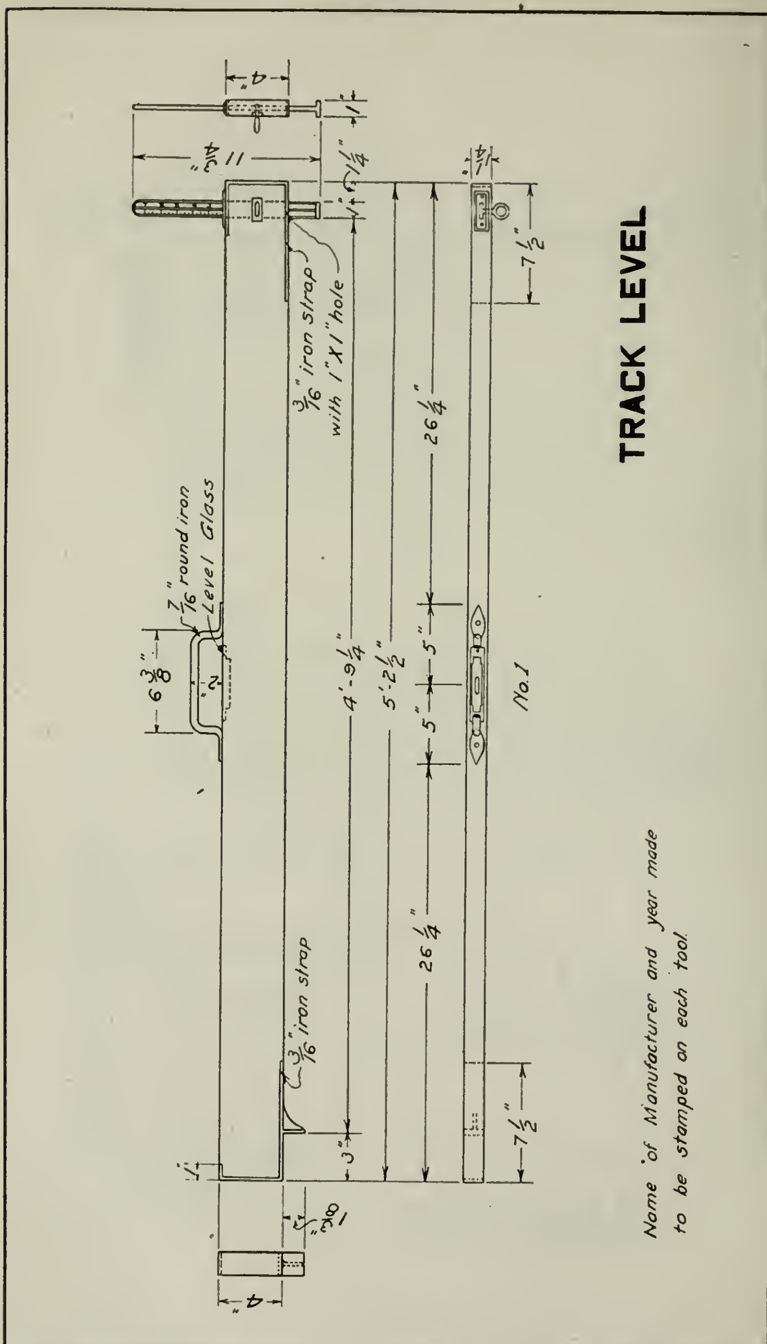


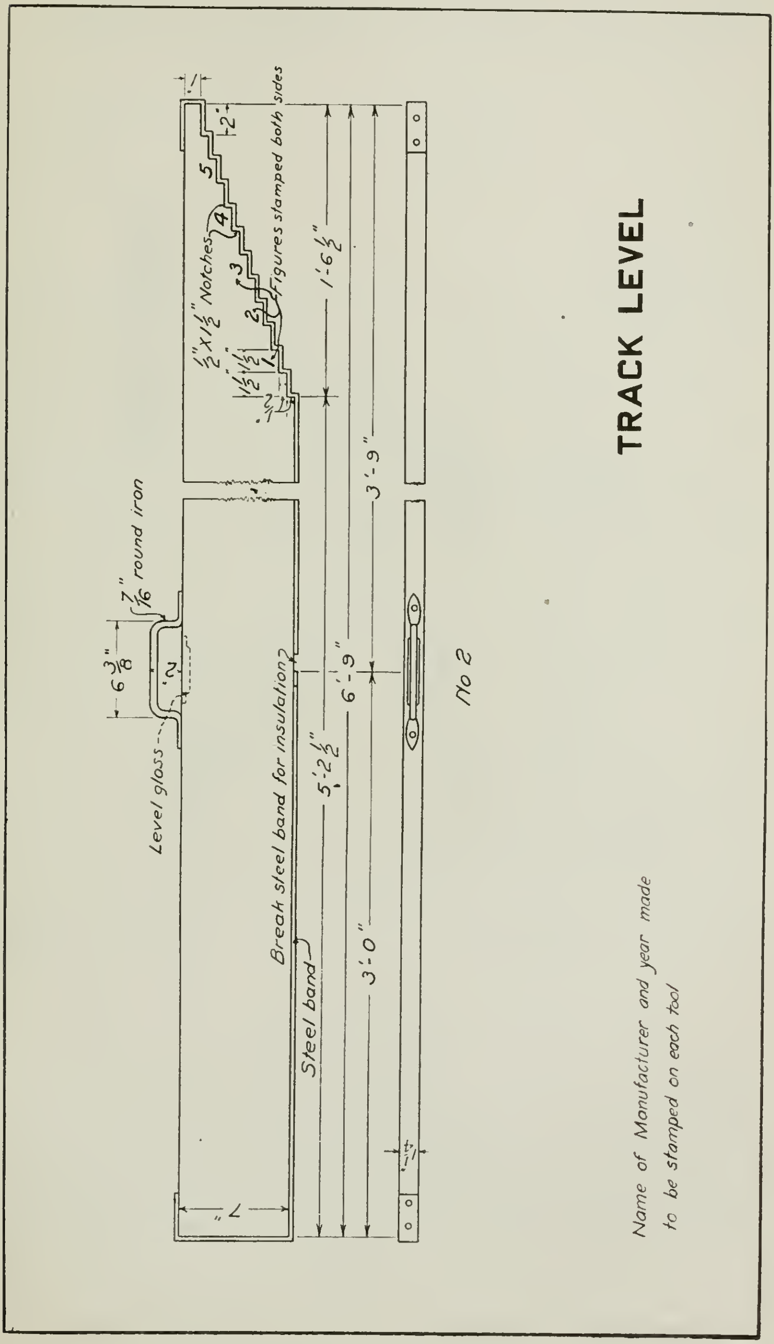
Note,
Name of Manufacturer and year made to be stamped on each sledge.



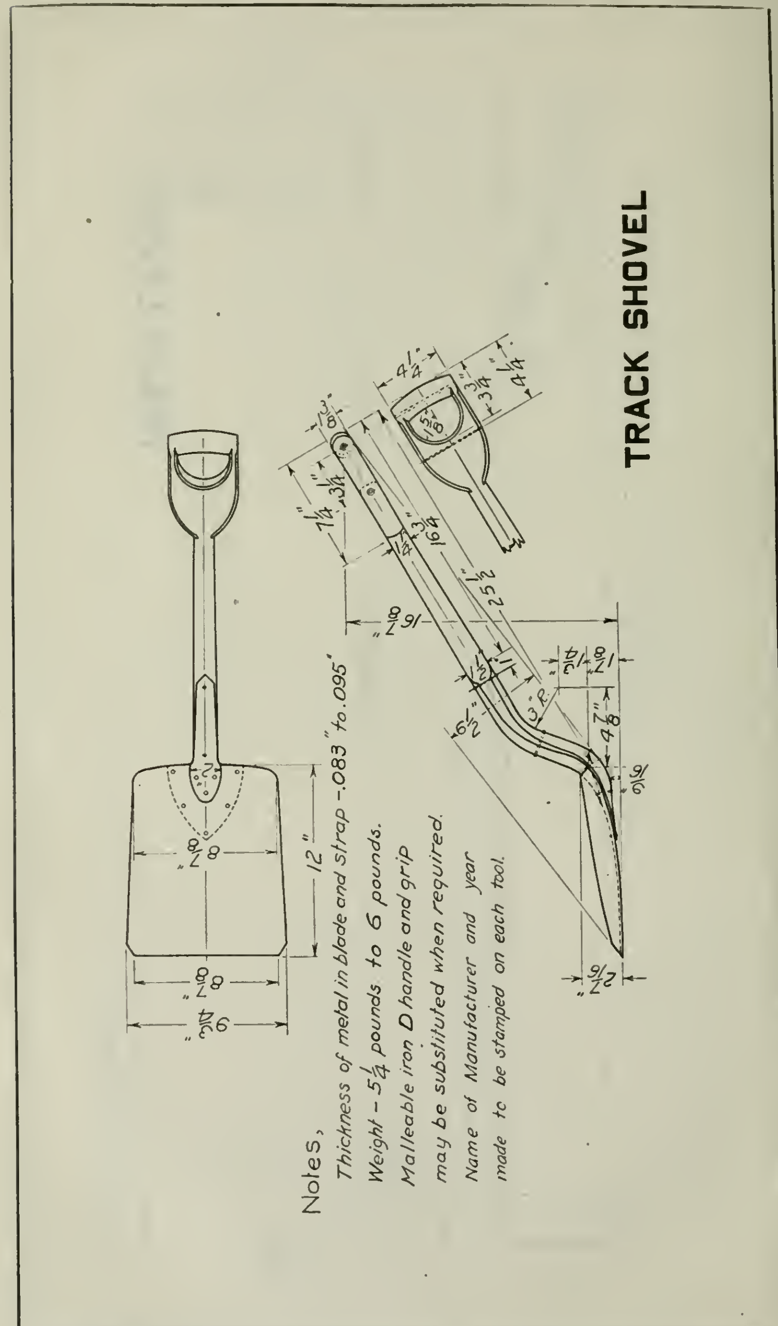
Approx Wt	A	B	C	D
6 Pounds	$6\frac{3}{4}$"	2"	$1\frac{1}{4}$"	$\frac{15}{16}$"
8 "	7"	$2\frac{3}{8}$"	$1\frac{1}{4}$"	$\frac{15}{16}$"
10 "	$7\frac{1}{4}$"	$2\frac{1}{2}$"	$1\frac{5}{16}$"	$1\frac{1}{16}$"
12 "	$7\frac{1}{2}$"	$2\frac{5}{8}$"	$1\frac{5}{16}$"	$1\frac{1}{16}$"
14 "	8"	3"	$1\frac{3}{8}$"	$1\frac{1}{8}$"

SLEDGE


TRACK LEVEL
Name of Manufacturer and year made
to be stamped on each tool.
No.1
3/16" iron strap
with 1"X1" hole
7/16" round iron
Level Glass
3/16" iron strap
4'-9 1/4"
5'-2 1/2"
26 1/4"
5"
5"
26 1/4"
7 1/2"
7 1/2"
6 3/8"
11 3/4"
4"
4"
3"



TRACK LEVEL
No 2
Level glass
$6\frac{3}{8}''$
$\frac{7}{16}''$ round iron
Break steel band for insulation
Steel band
$\frac{1}{2}''\times 1\frac{1}{2}''$ Notches
Figures stamped both sides
$1'-6\frac{1}{2}''$
$5'-2\frac{1}{2}''$
$6'-9''$
$3'-9''$
$3'-0''$
7"
Name of Manufacturer and year made
to be stamped on each tool


TRACK SHOVEL
Notes,
Thickness of metal in blade and strap -.083" to .095"
Weight - 5¼ pounds to 6 pounds.
Malleable iron D handle and grip
may be substituted when required.
Name of Manufacturer and year
made to be stamped on each tool.

Appendix D

(4) SPECIFICATIONS AND UNIT TRACK WORK SCHEDULES FOR CONTRACTING MAINTENANCE WORK

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W. P. Wiltsee,
L. B. Allen,
J. B. Baker,
H. G. Clark,
E. A. Hadley,
H. A. Lloyd,
J. B. Myers,
J. H. Reinholdt,
J. R. Watt,
Sub-Committee.

Owing to the abnormal conditions under which maintenance of way operations have been conducted during the past two or three years, increased attention has been given to the possibilities of contracting certain work. This tendency has been given an added impetus on account of the marked differential between the wages which the railways are required to pay their maintenance of way employees and those prevailing in other industries requiring similar skill.

While many roads have resorted to the cost plus form of contract in handling their maintenance of way work, this plan is in effect little more than a recognition of the contractor as a labor agent, the work being done as heretofore under the immediate direction and supervision of the regular railway officers. Such forms of contract are not considered to come within the limits of contract work which the Board of Direction had in mind when assigning this subject to the Track Committee. The Committee has, therefore, confined its attention to the consideration of those classes of track work which lend themselves to accurate measurement and which are subject to contracts based upon specific prices for given units of work.

While a considerable amount of maintenance of way work can be so arranged as to permit of such measurement and some railway officers even go so far as to suggest that all maintenance can be so measured, the Committee has confined its attention this year to the preparation of specifications and unit schedules for those classes of work which lend themselves most readily to unit measurements. Specifications and unit schedules are therefore presented for (1) the laying of rail, (2) the stripping of track, the removal of ties and the respacing of ties and (3) for ballasting.

SPECIFICATIONS FOR THE RELAYING OF RAIL

(1) The railway company's authorized representative shall arrive at a clear understanding with the contractor as to the force to be employed, the speed with which it is desired to have the work proceed, and the general traffic situation in the territory to be relaid, in order that proper plans may be made to proceed economically with the work specified. Prior to starting the work the contractor shall notify the railroad company's representative a sufficient time in advance so that speed and

traffic restrictions in the territory in which the work is to be performed may be arranged with the operating department of the railway company.

(2) Rail must be closed for all scheduled passenger trains and as soon as possible after arrival, for all freight trains.

(3) Rail may be closed temporarily for the passage of trains during the hours while the work is in progress, inserted according to the standards of the railway company. All connections left in the track over night must be made with rails of full section and standard angle bars or joints. The railway company shall provide and the contractor shall pay for competent flagmen during the continuance of this work, to flag in accordance with the rules of the company for the protection of the work and traffic.

(4) The railway company will unload and distribute all rail, joints, bolts, spikes, tie plates, rail anchors and other materials to be inserted in the track.

(5) The contractor shall provide all tools needed in connection with this work.

(6) The railway company will provide the necessary inspector or inspectors and the instructions of such inspectors regarding the quality and type of work to be done shall be complied with at all times by the contractor.

(7) The contractor shall supply the necessary foremen and labor to prosecute the work properly and in such numbers as may be required by the Chief Engineer or his authorized representative, and at the request of the Chief Engineer or his representative will remove any foreman or man not satisfactory to the railway company.

(8) Trains must not be permitted to use the track on tangents with spikes out of more than two consecutive ties and not more than six ties to any one rail, or on curves with the spikes removed from two consecutive ties. Proper gage must be maintained and all ties on which the rail does not have a full bearing must be tamped up and spikes driven down to avoid bending the rail.

(9) Track must not be allowed to go over night with spikes drawn in advance of the work.

(10) All spike holes must be plugged prior to adzing ties for rail or tie plate bearing.

(11) Ties must be adzed carefully, giving full bearing with the least possible cutting of ties. The bottom of the rail, the tie plate and the bearing surface of the tie shall be cleaned before the rail is laid. When replacing rail with rail of the same section, unless changing or adding tie plates, only two rows of spikes may be drawn, provided proper gage is maintained; in replacing rail with different section, three or four rows of spikes shall be drawn, as is necessary.

(12) Tie plates, when furnished, must be applied in a workmanlike manner at time rail is laid to avoid unnecessary spiking and must be so placed that the shoulder is in contact with the base of rail or the splice bar for the entire length of the shoulder.

(13) Metal expansion shims must be used to provide for the proper openings between the rails and a thermometer shall be used to determine the thickness of the shims to be used, in accordance with the standards of the American Railway Engineering Association.

(14) At the close of each day's work all joints shall be full bolted, the bolts made tight and the rail full spiked.

(15) Necessary gaging must be done at the time rail is laid and should conform to the railway company's standard practice.

(16) Old rail must be left parallel with the track with joints uncoupled and all old bolts, nuts, spikes, tie plates, joints, etc., must be gathered up and left in neat piles on the ground, separated as between usable and scrap material in accordance with the railway standards, convenient for picking up by work trains.

(17) Excess material distributed for rail laying must be picked up by the contractor and taken ahead where it can be used.

(18) In laying rail on tangents the staggering of joints must be provided and in laying rail on curves care must be taken to put in short length rails at proper intervals in the low rail and to maintain the proper stagger throughout the curve.

(19) As far as possible all joints should be kept out of street and road crossings, using long or short rails for this purpose.

(20) Rails must be spiked in full to each tie. The inside and outside spikes shall be as far apart as the face and character of the tie will permit. The inside spikes shall be on the same side of the tie.

(21) All spikes shall be started vertically and square with the rail and so driven that the face of the spike shall have a full hold on the base of the rail. Spikes must not be straightened while being driven.

(22) Spikes must be drawn carefully with a view of using them again.

(23) All switches, frogs and guard rails must be placed in accordance with the railway company's standards.

(24) Switches must be left in proper adjustment, special care being given to bending of the stock rail.

(25) The contractor must restore and secure promptly all stockguards, crossing plank, or other facilities displaced by reason of the rail laying, and must replace all safety and foot blocking removed in changing out switches, frogs and guard rails.

(26) The contractor is to understand that any work not specifically mentioned in the specifications, but which is necessary, either directly or indirectly, for the proper carrying out of the intent thereof, shall be required and applied, and he shall perform all such work just as if it were particularly delineated or described. Unless specifically mentioned above, all work shall conform to the standards of the railway company.

Unit Track Work Schedules for Renewing Rails Out of Face

Suggested form of unit track work schedule to be compiled from data collected by making a series of time studies of actual rail laying performances.

Time distribution based on ten 100-lb. rails laid with six-hole plain bars replacing rail of lighter weight, fully tie plated and applying new tie plates out of face. (Typical figures shown in parenthesis.)

Operation	*Minutes for 10 Rails*
Drawing two lines of spikes	(180)
Lining out old rail	(60)
Taking off old tie plates	(40)
Plugging spike holes	(50)
Adzing	(154)
Cleaning rail seat	(18)
Placing new tie plates	(100)
Setting in new rail	(90)
Distributing bolts, nut locks, spikes, and tie plates	(54)
Placing splice bars and full bolting	(130)
Gaging and full spiking	(220)
Uncoupling old rail	(120)
Flagmen during runs, two	(84)
Water boys, two	(54)
Foremen, three	(81)
Total time for ten rails	(1435)
Total minutes per foot	(4.346)
Standard schedule in hours per 33-ft. rail	(2.39)
To be considered as 100 per cent efficiency.	

Making Connections

Add to the standard hours computed for laying rail, additional hours for making connections as follows:

For each connection made, add (one) per cent of the total hours on rail laying reported for the day's work.

Example

A gang of 45 men laid 160, 33-ft. rails in a ten-hour day and made four connections. A 10 per cent allowance is made for detention on account of going to and from work and getting out of the way of passing trains.

160 x 2.39	382
4 connections, 4% of 450 hours	18
Total standard hours	400
Total hours made by gang	450
Total hours detention	45
Total actual hours worked laying rail	405

Efficiency = 400 + 405 = 98.7 per cent.

Specifications for the Ballasting of Track by Contract

(1) The railway company's authorized representative shall arrive at a clear understanding with the contractor as to the force to be employed, the speed with which it is desired to have the work proceed, the source of ballast supply and the general traffic situation in the territory to be ballasted, in order that proper plans may be made to proceed economically

with the work specified. Prior to starting the work the contractor shall notify the railway company's representative a sufficient time in advance so that speed and traffic restrictions in the territory in which the work is to be performed may be arranged with the operating department of the railway company.

(2) The railway company will provide the necessary inspector or inspectors, and the instructions of such inspectors regarding the quality and type of work to be done shall be complied with at all times by the contractor.

(3) The contractor shall supply the necessary foremen and labor to prosecute the work properly and in such numbers as may be required by the Chief Engineer or his authorized representative, and at the request of the Chief Engineer or his representative will remove any foreman or man employed not satisfactory to the railway company.

(4) The railway company shall provide and the contractor shall pay for competent flagmen during the continuance of this work, to flag in accordance with the rules of the company for the protection of the work and traffic.

(5) Where required, banks shall be widened to the proper width prior to starting ballast work and a sufficient time in advance so that there will be no interference. Such widening of embankments and the proper grading of public or private crossings shall be done by the railway company unless specific instructions are given by the representatives of the railway company to the contractor to do such work.

(Note.—If contractor is to do bank widening work, specifications for such work must be provided.)

(6) Grade stakes will be set to the proper grade by the representative of the railway company before the ballast material has been dumped and spread.

(7) All tile, box or other drains required to take care of water between the tracks shall be placed before the ballast material is unloaded.

(8) The railway company will supply all equipment and train crews required for the loading, transporting, unloading and spreading of the ballast. The contractor shall supply all tools needed in connection with this work.

(9) The railway company shall furnish all ballast as required in its own cars and shall transport and switch such ballast free of cost to the contractor to the point where it is to be applied.

(10) Ballast shall be unloaded by the contractor by dumping or plowing as the means provided by the railway company permit. If the ballast is in center dump cars it shall be unloaded by having one or more cars opened at a time, allowing the required amount of ballast material to flow out as the train is moved along slowly. If the material is on flat or open cars, it shall be plowed off by means of an unloading machine while the train is moving at such a rate of speed as to provide the desired amount of material as uniformly distributed as possible. The unloaded material shall be leveled down by means of a ballast plow or

spreader. Care shall be taken not to destroy or disturb the grade stakes.

(11) The preliminary surfacing gang shall follow the unloading as closely as the regularity of the ballast supply will permit. In using jacks, they must be placed close enough together to prevent undue bending of the rail or strain on the joints. Both rails must be raised at one time and as nearly uniformly as possible. The track shall be so lifted that after a period of not less than three days after the last lift it will be necessary to give it a final lift of not less than one inch nor more than two inches to bring it to the grade of the stakes. All ties that are pulled loose or renewed shall be replaced to proper position and must have a bearing against the rail and be fully spiked, with all spikes driven home before tamping. In driving spikes, all spikes shall be started vertically and square with the rail, and so driven that the base of the spikes shall have a full hold on the rail. Spikes must not be straightened while being driven. Ballast shall be well packed or tamped with pick, shovel, tamping bar or tamping machine, as directed, from a point fifteen inches inside of each rail on both sides of the ties to the end of the ties, tamping the outside of the tie first.

(12) When the track has been raised to within one or two inches of the final grade and properly compacted by traffic, a finishing lift shall be made by jacking up the track to the exact height provided for by the grade stakes. All allowance for settlement shall be taken care of in the setting of the stakes and the necessary ballast forked or shoveled in, and then driven to place by tamping machines, tamping picks, bars or shovels, as directed by the proper representative of the railway company. In making the finishing lift the spot board and level board must be used with care and the track brought to as true a surface as possible.

(13) The track shall be placed in good alinement before the finishing lift is made, but a lining gang shall follow one or two days behind the finishing lift and shall spot up all places found not to be holding up to proper surface, and shall line the track to as accurate an alinement as possible. Center stakes shall be set for the alinement before the finishing lift is made and the final alinement must conform to the center stakes.

(14) The contractor shall trim the ballast to conform to the standard roadbed section, and the railway company for this purpose shall supply its standard cross-section template. The portion of the sub-grade outside the ballast line shall be left with a full even surface and the shoulder of the embankment properly dressed to the standard roadbed section. The contractor shall dispose of any surplus ballast after trimming the ballast section as directed by the representative of the railway company.

(15) The contractor must restore and secure promptly all stock-guards, crossing plank, or other facilities displaced by reason of the ballasting.

(16) After ten days' use of the track by the railway company the contractor shall go over same and surface and line low joints and spots which may have developed without extra charge to the railway company.

(17) The contractor shall remove from the railway company's property all rubbish and waste from any ballast work, or dispose of it as directed by the representative of the railway company. After completing the work the contractor shall remove from the railway company's property, and from all public and privately-owned property, at his own expense all temporary structures and waste resulting from his camping operations.

(18) In measuring the work, lining, surfacing and trimming turnouts and crossovers shall be considered as main track.

(19) The contractor is to understand that any work not specifically mentioned in the specifications, but which is necessary, either directly or indirectly, for the proper carrying out of the intent thereof, shall be required and applied, and he shall perform all such work just as if it were particularly delineated or described. Unless specifically mentioned above, all work shall conform to the standards of the railway company.

Unit Track Work Schedule for Ballasting

Suggested form for unit track work schedules for ballasting. Where track is at present ballasted with cinders, granulated slag, or gravel, and is to be renewed with stone ballast, track to be given two raises on stone, tamped with forks, and given a final out-of-face surfacing with picks. Track to be dressed to standard stone ballast section and to have 12 inches of ballast under the ties.

Separate schedules to be used for stripping track, respacing ties and renewing ties, which work is to be done ahead of the unloading of stone ballast.

The second dumping of ballast to be heavy enough so that after the second raise the cribs will be only about one-half full. This will allow the final surfacing (with tamping picks) to be done with the minimum amount of labor for cribbing out ballast, and will leave sufficient ballast around the ties to keep them in place until the ballast is dumped for dressing. (Typical figures shown in parenthesis.)

Raising Track

Operation	*Time Distribution Minutes Per Foot of One Track*
First Raise of Six Inches	
Running spot board	(0.07)
Digging jack holes	(0.71)
Jacking up track	(0.70)
Running level board	(0.15)
Tamping (forks)	(2.10)
Water boy	(0.20)
Foreman (assume gang of 20 men)	(0.20)
Second Raise of Six Inches	
Running spot board	(0.07)
Digging jack holes	(0.71)
Jacking up track	(0.85)
Running level board	(0.20)
Tamping (forks)	(4.10)
Water boy	(0.30)
Foreman (assume gang of 20 men)	(0.30)

Surface Raise of 0 to 2 inches

	Time Distribution Minutes Per Tie	
Jacking up track	(0.40)	
Running level board	(0.18)	
Cribbing out ballast	(1.50)	
Tap down spikes	(0.76)	
Tamp both ends one tie on both sides and for 18 in. each side of rail	(13.00)	
Water boy	(0.25)	
Foreman (assume gang of 20 men)	(1.02)	
Total per tie	17.11	
Total surface lift per foot of track		9.33

Dressing (Single Track)

Building berms (2)	(1.40)
Building shoulder lines (2)	(0.60)
Taking ballast from between rails	(3.30)
Dressing ballast shoulders (2)	(1.60)
Water boy (part time)	(0.40)
Foreman	(0.70)
Flagmen (2) to protect entire organization	(1.86)

Note:

In dressing double track add to above—
3.3 for ballast from between rails,
0.9 for dressing center ditch,
0.4 for foreman,

Total minutes per foot of track	29.85
Standard schedule in hours per foot of one track	0.497

Example

A gang of 90 men complete 1,676 ft. of track in a ten-hour day and is allowed a 10 per cent detention for going to and from work and getting out of the way of passing trains.

Total standard hours — $1676 \times .497 = 732.97$.

Total hours made	900
Total hours detention	90
Total actual hours ballasting	810

Efficiency $= 732.97 \div 810 = 90.4$ per cent.

SPECIFICATIONS FOR THE STRIPPING OF TRACK, THE RENEWAL OF TIES AND THE RESPACING OF TIES

(1) The railway company's authorized representative shall arrive at a clear understanding with the contractor as to the force to be employed, the speed with which it is desired to have the work proceed, the source of ballast supply and the general traffic situation in the territory in question, in order that proper plans may be made to proceed economically with the work specified. Prior to starting the work the contractor shall notify the railway company's representative a sufficient time in advance so that speed and traffic restrictions in the territory in which the work is

to be performed may be arranged with the operating department of the railway company.

(2) The railway company shall furnish the ties required for renewal purposes at convenient points along the right-of-way.

(3) The contractor shall supply all tools needed in connection with this work.

(4) The railway company shall provide the necessary inspector or inspectors and the instructions of such inspectors regarding the quality and type of work to be done shall be complied with at all times by the contractor.

(5) The contractor shall supply the necessary foremen and labor to prosecute the work properly and in such numbers as may be required by the Chief Engineer or his authorized representative, and at the request of the Chief Engineer or his representative will remove any foreman or man employed not satisfactory to the railway company.

(6) The track shall be skeletonized not to exceed two days in advance of the unloading of the ballast. Where the old material is suitable for sub-ballast and conditions permit the raising of the track, it will be raised and the old material spread under and between the ties to the proper width as uniformly as practicable. When conditions do not permit the raising of the track, the old material shall be removed to the required depth and disposed of as directed, or where the material is not suitable for sub-ballast, it shall be removed to the plane of the bottom of the ties, or deeper if necessary to preserve the grade line, and shall be placed on the outer shoulder of the roadbed, preferably at such points as will tend to even up the line of the shoulder. Upon the completion of this work the surface of the sub-grade shall be sloped with reasonable uniformity so as to provide proper drainage to the shoulder of the embankment.

(7) Following the skeletonizing of the track, all old ties which are not fit for more than one year in track where gravel or cinder ballast is to be used, or for more than two years in track where stone or hard slag is to be used, shall be removed and new ties inserted in their places. The largest and best ties shall be used at the joints. The heart side of ties should generally be turned down but they should be laid so as to obtain the best bearing. The adzing shall be done carefully and so as to provide full bearing for the tie plate or rail, with the least cutting possible to obtain bearing on solid wood.

(8) On single track ties shall be lined with the line rail on tangents, and with the inside rail on curves. On double track ties shall be lined to the outside of both tracks. Where there are sidetracks on each side of the main track, the side track ties must be lined to the outside of such tracks.

(9) Picks should not be stuck into a tie to drag it into place, nor should ties be struck on the end with a tamping pick or spike maul. Tie tongs should be used to handle all ties.

(10) When old ties are taken from track, all tie plates and spikes

must be carefully removed and preserved. The old ties shall be neatly piled for such inspection and disposition as the railway company's rules require.

(11) Ties should not be stood on end in close cuts.

(12) All treated ties shall be dated and where standard galvanized dating nails are used they shall be applied the day the ties are placed in the track. The position of the nail should be in accordance with standard instructions for that year.

(13) The spiking of the rails shall be done as directed by the railway company's representative. Where splices are slotted, spikes must be driven in the slots, except on bridges and open deck trestles, where spikes must not be driven either in the slots or against the ends of the splices. Two spikes shall be used with tie plates except when otherwise directed by the railway company's representative, only good or new spikes to be used. Spikes must be driven plumb and touching the base of the rail, so that when driven they will hold the rail to gage, and the under side of the head will have full bearing on the base of rail. They must be driven down until the head is tight against the rail, but no further blows should be struck after the spike has been driven home. Every hole from which a spike is drawn must be plugged in advance of the adzing. Spikes must be drawn carefully with a view of using them again.

(14) Joint ties shall be spaced in accordance with the railway company's standard plans, intermediate ties shall be spaced uniformly and all ties shall be laid square with the rail. The number of ties per rail shall be as required by the railway company's standard plans.

(15) The contractor is to understand that any work not specifically mentioned in the specifications, but which is necessary, either directly or indirectly, for the proper carrying out of the intent thereof, shall be required and applied, and he shall perform all such work just as if it were particularly delineated or described. Unless specifically mentioned above, all work shall conform to the standards of the railway company.

UNIT TRACK WORK SCHEDULE FOR THE STRIPPING OF TRACK—SINGLE

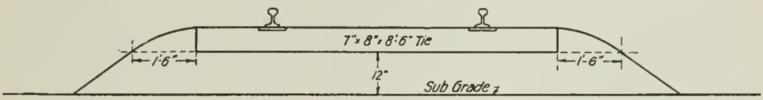
Suggested form of unit track work schedule to be compiled from data collected by making a series of time studies of actual performances. The old cinder, slag or gravel ballast to be cleaned out to level of bottom of ties, and placed on the banks for widening or piled so it can be disposed of with wheelbarrows or work trains. (Typical figures shown in parenthesis.)

Schedule given is for standard section of single track.

Operation	*Time Distribution, Removing One Cubic Yard of Material, Includes Foreman's Time*
Cribs	23 min. = (.38) hr.
Shoulders	26 min. = (.433) hr.
Standard schedule hours per linear foot of single track = 100 per cent efficiency	(0.101) hr.

For double track on 13 ft. centers, including center ditch, add as follows:

Cribs in one additional track.................................... .38 hr.
Center ditch .... .433 hr.
Standard schedule hours per linear foot of double track = 100 per cent efficiency .... (0.23) hr.



STRIPPING TRACK—(Single)

Cribs per foot of single track................3.16 cu. ft. = 0.117 cu. yds.
Shoulders (2) per foot single track..........0.83 cu. ft. = 0.031 cu. yds.
Center ditch per foot double track...........2.62 cu. ft. = 0.097 cu. yds.

Cubic Contents

For stripping 1 linear foot single track..........3.99 cu. ft. = .15 cu. yds.
For stripping 1 linear foot double track..........9.77 cu. ft. = .36 cu. yds.

EXAMPLE

A gang of 16 men working a ten-hour day strips 1,605 feet of single track and has a 10 per cent detention account going to and from work and getting out of the way of passing trains.

Total standard hours.................1605 × .101 = 162.1

Total hours made.................................. 160
Total hours detention 16

Total actual hours 144

Efficiency = 162.1 ÷ 144 = 112.6%.

UNIT TRACK WORK SCHEDULE FOR RESPACING TIES

Suggested form of unit track work schedule to be compiled from data collected by making a series of time studies of actual performances. It is considered that the respacing of ties will be done following the work of stripping the track and just ahead of the tie renewal gang, and should be a unit of the tie renewal organization, although a separate schedule is provided. (Typical figures shown in parenthesis.)

Operation	*Time Distribution Minutes per Tie*
Moving tie to place	(1.9)
Percentage of foreman and water boy's time	(.2)
Total minutes for one tie	(2.1)
Standard schedule hours per tie	(.035)

Where necessary to tamp the tie after respacing add the following to the above schedule:

	Time Distribution, Minutes per Tie.
Tamp one end of tie outside of rail	(.50) min.
Tamp one end of tie inside of rail	(.50) min.
Total per tie end	(1.0) min.
Total per tie both ends	(2.0) min.

Standard schedule hours:

Per one tie end	(.0334)
Per tie both ends	(.0167)

If only cross-tamping is done, use one-half the above scheduled hours for tamping.

Appendix E

(5) PLANS AND SPECIFICATIONS FOR SWITCH STANDS, SWITCH LAMPS AND SWITCH LOCKS

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V. Angerer,
C. W. Breed,
E. A. Hadley,
W. S. McFetridge,
F. L. Nicholson,
G. J. Slibeck,
J. B. Strong,
J. R. Watt,

Sub-Committee.

In Appendix A, Item II, plan 252, covering details of lamp tips for switch stands, is submitted for adoption as a supplement to the Manual, completing Section 12 of Requisites for Switch Stands, including Connecting Rods, adopted March, 1921.

The plan showing shapes and sizes of targets, No. 253, dated November, 1921, to complete Section 11 of Requisites for Switch Stands, including Connecting Rods, is presented with the Committee's recommendation that it be accepted as information only.

Your criticism of this plan is invited, that it may be considered for revision if found desirable and resubmitted next year for adoption. It was found there are at present in service a great variety of dimensions of the same shape or style, the dimensions in some instances varying by only a fraction of an inch, each set of dimensions requiring individual dies. Hence, an effort has been made to standardize the dimensions of styles in most common use and show a sufficient variety of shapes and sizes to meet various operating requirements. After consultation with the A.R.A. Signal Section it was found they had no standard target shapes, their only standard being a 10-inch target disc for attachment to switch lamps.

The Committee submits plan No. 254 of 10-inch and 9-inch day target discs for attachment direct to switch lamps for low and extra low switch stands, and recommends that it be adopted as standard. This is an outline plan only and conforms to dimensions on A.R.A. Signal Section plan No. 1445 for the 10-inch day disc, to which reference is made for further details.

The Committee also recommends that the following A.R.A. Signal Section plans of switch lamps be approved and endorsed without publication in our records:

Plan 1440—Switch lamp (spherical type), approved March, 1921.

Plan 1441—Switch lamp base-socket for spherical type switch lamp (Plan 1440), approved March, 1921.

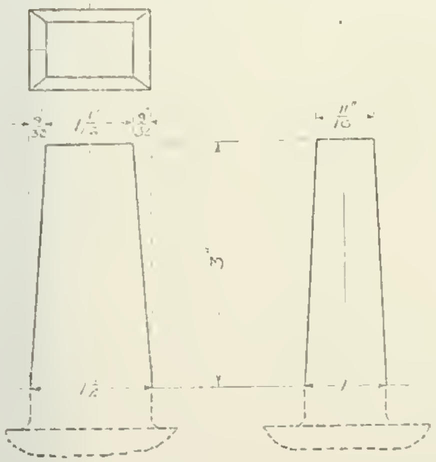
Plan 1442—Lens, hoods and couplings for switch and semaphore lamps (see plans 1440 and 1460), approved March, 1921.

Plan 1443—Oil fount for spherical type lamp (Plan 1440), approved March, 1921.

Plan 1460—Switch lamp (cylindrical type).
Plan 1461—Switch lamp base-socket for cylindrical type switch lamp (Plan 1460).

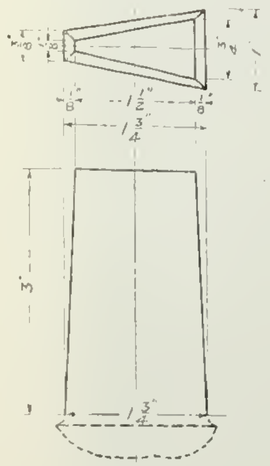
It is the opinion of the Committee that a further investigation should be made with a view of recommending an additional design of lamp, of reduced height, for use with low and extra low switch stands and for close clearances.

The subject of switch locks has been investigated, but the Committee is not yet ready to make a report.

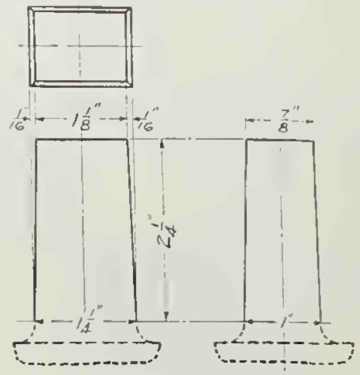


G1

A.R.A.. Sig. Div. Standard.

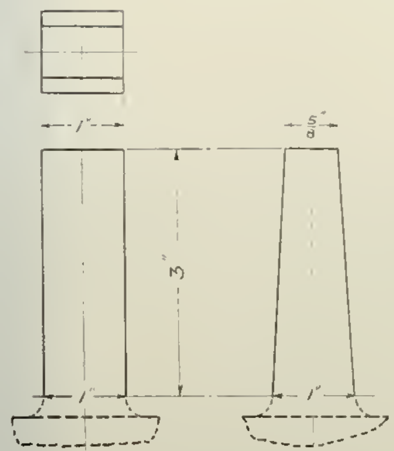


G2

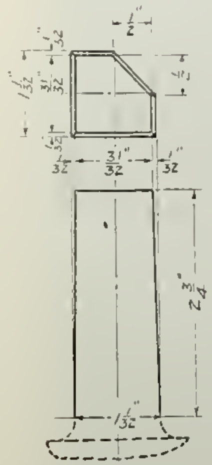


G3

Note:
Cast Tips may be channelled within $\frac{1}{4}$" of fitting Edge.
For Lamps whose Colors cannot be reversed 180° use either G2 or G5 Lamp Tip.



G4



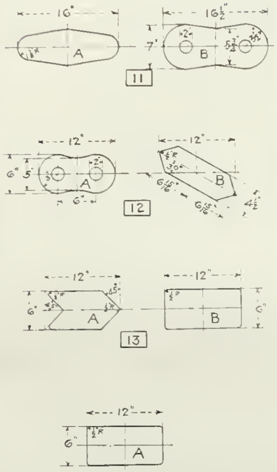
G5

DETAIL OF LAMP TIPS
FOR
SWITCH STANDS

NOVEMBER, 1921.

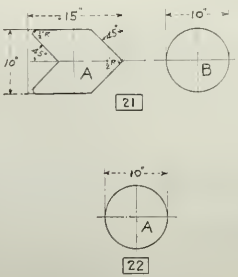
PLAN Nº 252

TARGETS FOR LOW SWITCH STANDS



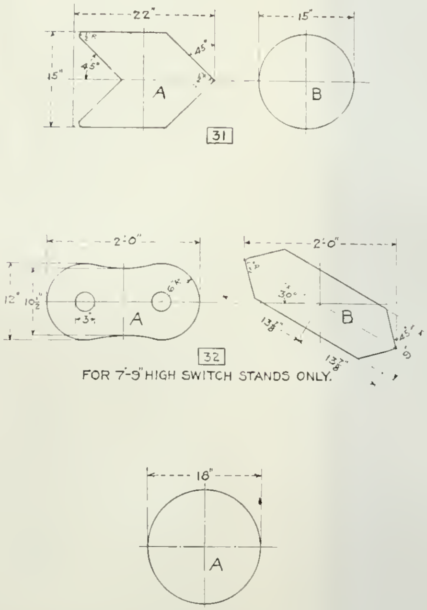
SINGLE VANE TARGET

TARGETS FOR 4'-0" INTERMEDIATE SWITCH STANDS



SINGLE VANE TARGET

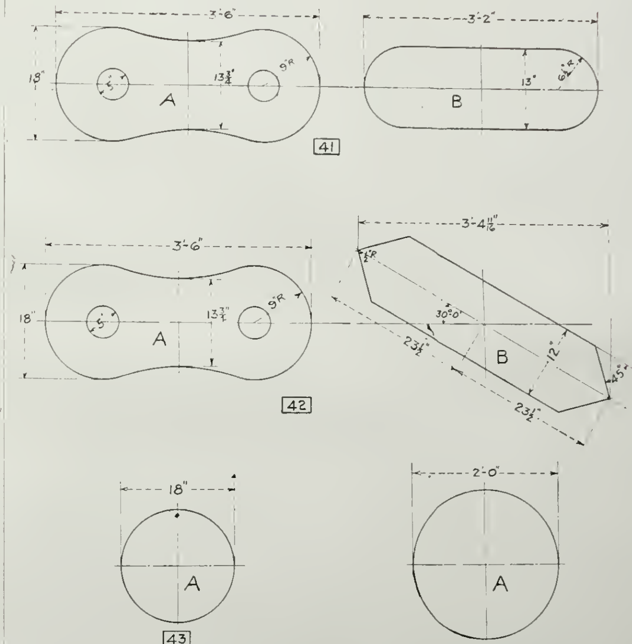
TARGETS FOR 6'-0" & 7'-9" INTERMEDIATE SWITCH STANDS



FOR 7'-9" HIGH SWITCH STANDS ONLY.

33 SINGLE VANE TARGET

TARGETS FOR HIGH SWITCH STANDS



43 SINGLE VANE TARGET

44 SINGLE VANE TARGET

NOTE:- STANDARD CLASSIFICATION OF SWITCH STANDS

A.- High Switch Stands:
- Height greater than 14'-0"
- Standard Height 18'-0"

B - Intermediate Switch Stands:
- Height greater than 2'-0"
- To and Including 14'-0"
- Standard Heights:
  - (a) First Intermediate 7'-9"
  - (b) Second Intermediate 6'-0"
  - (c) Third Intermediate 4'-0"

C - Low Switch Stands:
- Height greater than 1'-0"
- To and including 2'-0"

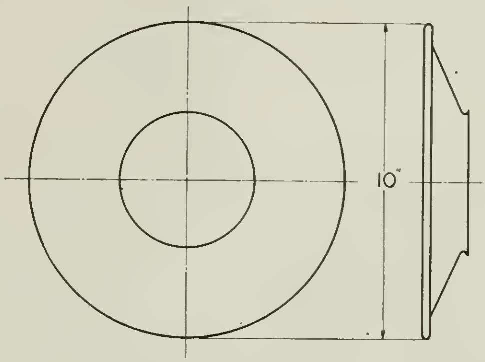
D - Extra Low Switch Stands:
- Height 1'-0" or less.

Note:- Extra Low Switch Stands are for general use with target lamps without separate targets.
Height of Switch Stands is measured from top of tie to bottom of taper of lamp tip.

DETAIL OF SWITCH STAND TARGET SHAPES

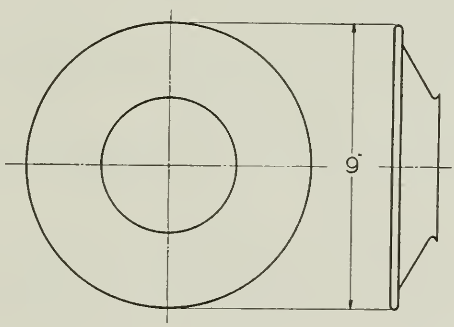
NOVEMBER, 1921.

PLAN Nº 253



51

10" DAY TARGET DISC



52

9" DAY TARGET DISC

NOTE:-

DAY DISCS TO BE USED FOR ATTACHMENT DIRECT TO SWITCH LAMPS FOR LOW AND EXTRA LOW SWITCH STANDS.
IN ORDERING DAY DISC SIZE OF LENS MUST BE GIVEN.

TABLE FOR DAY DISCS WITH STANDARD LENSES

FOCAL DISTANCE	DIAMETER	
	LENS	DISCS
$2\frac{3}{4}$"	4"	9"
	$4\frac{1}{8}$	9
3"	$4\frac{1}{2}$	9"
$3\frac{1}{2}$"	5"	10"
	$5\frac{3}{8}$	10"

DAY TARGET DISCS FOR SWITCH LAMPS

NOVEMBER 1921

PLAN № 254

Appendix F

(6) GAGES AND FLANGEWAYS FOR CURVED CROSSINGS

V. Angerer, *Chairman;*	H. A. Lloyd,
W. P. Wiltsee,	J. deN. Macomb,
J. V. Neubert,	W. S. McFetridge,
J. B. Baker,	G. J. Slibeck,
R. A. Baldwin,	J. B. Strong,

Sub-Committee.

Tables No. 1 and No. 2 are submitted in Appendix A, Item III, for adoption and publication in the Manual.

Table No. 1 is submitted as a suggested solution for "Concrete Rules for Recommended Practice" in the widening of gages and flangeways in curved track and curved crossings.

Table No. 1 is based on the theoretical study submitted in last year's report. The columns on the left give the approximate rigid wheel base of locomotives in combination with the number of pairs of flanged drivers stated that will operate on the gage of the track shown on the right under "Degrees of Curvature." Two columns are given for the wheel bases; one for plain, unguarded curves, and the other for guarded curves and curved crossings.

On a plain, unguarded curve the gage is determined by the largest wheel base locomotive operated over it, full allowances being made for play at journal boxes and tight setting of end drivers, when there are more than three pairs of flanged drivers.

On a guarded curve the width of the inside flangeway is determined by the largest locomotive and in which the gain from play at journal boxes is reduced by one-half the amount of the tight setting of end drivers. The outside rail must then be set a sufficient distance from the inside guard line so that the flanges of the outside wheels of smaller locomotives and four-wheel trucks will clear the outside rail and frog points when the inside wheels bear against the inside guard, thus determining the gage necessary to make the guard effective. The outside guard rail has to be set the same distance from the inside gage line as a maximum to give clearance for the center drivers of locomotive when these center drivers are forced towards the inside gage line by the contact of the end drivers on the inside guard. This distance made 4 ft. 6¾ in. gives a theoretical clearance of $\frac{3}{32}$-in. with normal wheel setting. The diagram sketch illustrates the above conditions in the operation of locomotives and four-wheel trucks over the same guarded curve. The gage for guarded curves given in the table having thus been determined from the flangeway, the width of flangeway can be found by deducting the 4 ft. 6¾ in. from the gage.

In the calculations by the formulæ given in last year's report the diameter of the wheels has been assumed to be the maximum permitted by the wheel base. The allowances for lateral play at journal boxes and tight setting of outside drivers as per Note 4 are in accordance with average practice of locomotive builders, but there is no strict uniformity.

More play would permit a corresponding reduction in the width of flangeway and gage.

Particular attention is called to Note 5 on the table, which contains recommendations as to what width of gage may be used when no definite data as to the kind of locomotives to be operated over a given curve or curved crossing are available.

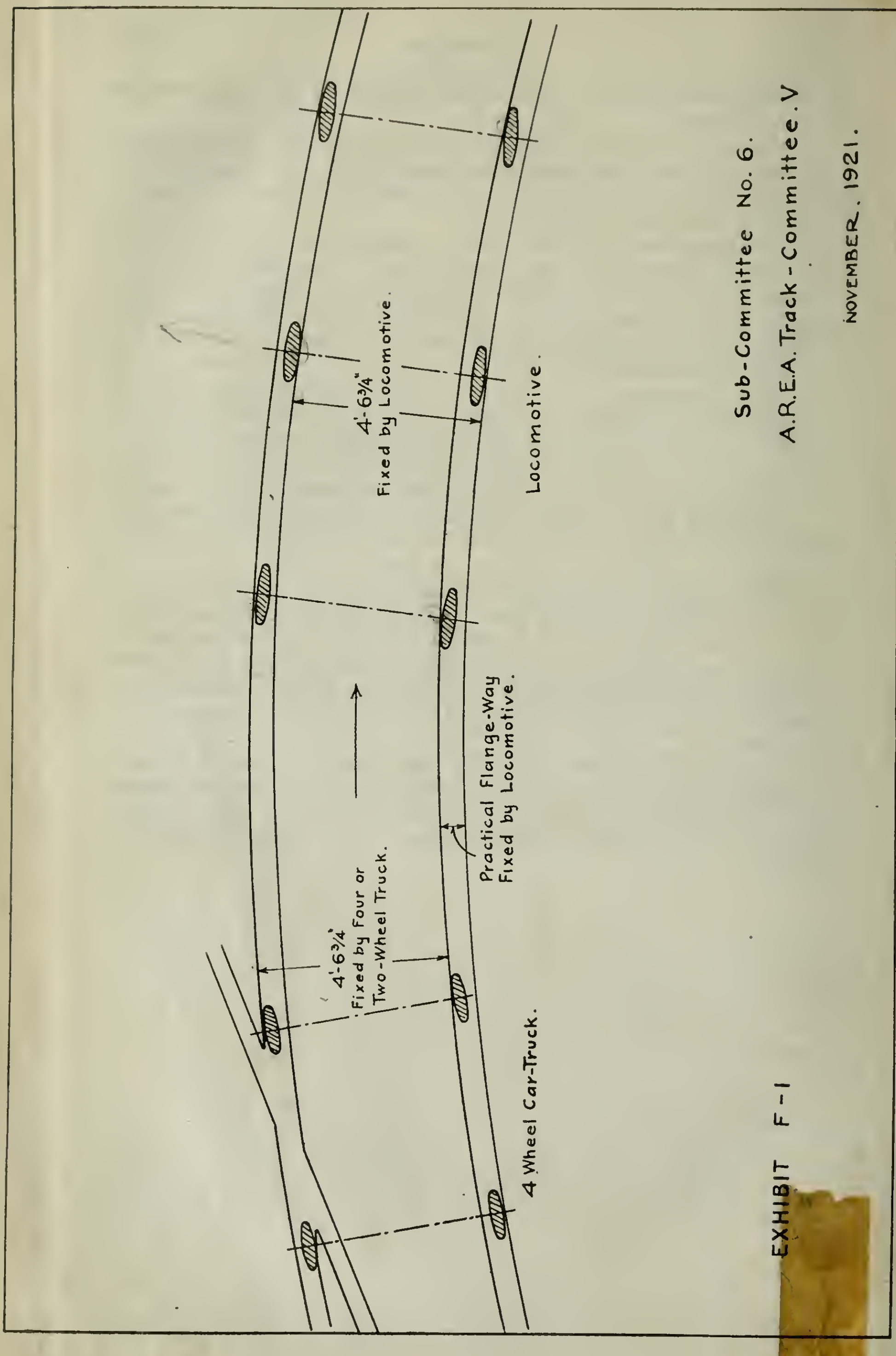
The gages designated under series "A" conform to the rule for "Gage on Curves" given in the 1915 Manual, page 117; the present tabulation shows the limits of the wheel bases of locomotives to which this rule will apply. Gages designated under series "B" are narrower gages, which would answer average conditions in yards and sidings, where main line locomotives do not operate.

Wide flangeways in crossings are apt to produce excessive wear through the pounding of the wheels in going across the flangeway. By Note 6 it is recommended that crossings should, wherever possible, be limited to 4 ft. 9 in. gage, 2¼-in. flangeway and the corresponding curvature permitting this limit for the equipment operated over the crossing.

Table No. 1 is sufficiently correct for general practical purposes. The figures for the gage are within ⅛ in. and the figures for the wheel base within 6 in. in order to avoid the use of smaller fractions.

For finding the more nearly exact gage necessary for a given locomotive on a given curve in cases where it may be desirable, the graphic table No. 2 is also submitted. The diagrams on Table No. 2 may be read to a small fraction of an inch. For other wheel bases than those shown, additional lines may be interpolated. A comparison of the readings of the diagrams with the figures on Table No. 1 will show the fractional differences.

The figures have been verified by some observations and some comparisons with actual practice and conditions. They have also been examined, including the recommendations contained in Notes 5 and 6, and are endorsed by the crossing builders, members of the Manganese Track Society.


Sub-Committee No. 6.
A.R.E.A. Track-Committee. V
NOVEMBER, 1921.
4'-6¾"
Fixed by Locomotive.
Locomotive.
Practical Flange-Way
Fixed by Locomotive.
4'-6¾"
Fixed by Four or
Two-Wheel Truck.
4 Wheel Car-Truck.
EXHIBIT F-1

GAGES AND FLANGE-WAYS IN CURVED TRACK.

TABLE No. 1.

RIGID WHEEL-BASE OF LOCOMOTIVE AND NUMBER OF FLANGED DRIVERS.										GAGE.													
5 PAIRS ALL FLANG'D DRIVERS SEE NOTE 2.		5 PAIRS OF DRIVERS CENTER DRIVER BLIND		4 PAIRS ALL FLANG'D DRIVERS		3 PAIRS ALL FLANG'D DRIVERS		2 PAIRS ALL WHEEL-BASES, SEE NOTE 1.		DEGREE OF CURVATURE.													
										33°	30°	28°	26°	24°	22°	20°	18°	16°	14°	12°	10°	8°	6°
						"G"	"P"			4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"	4'-8½"
							11'-0"	WHEEL-BASE		4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"	"	"
						11'-0"	11'-6"	"		4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"	"
						11'-6"	12'-0"	"		4'-9⅛"	4'-9"	4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8⅝"	4'-8½"	"	"	"	"	"
				"G"	"P"	12'-6"	13'-0"	"		4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"	"
					15'-0"	13'-6"	14'-0"	"			4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"	"
				15'-0"	16'-0"	14'-0"	15'-0"	"	B			4'-9½"	4'-9⅜"	**4'-9¼"**	**4'-9⅛"**	**4'-9"**	**4'-8⅞"**	**4'-8⅞"**	**4'-8¾"**	**4'-8⅝"**	**4'-8½"**	"	"
		"G"	"P"	16'-0"	17'-0"	15'-0"	15'-6"	"					4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"	"	"
			19'-0"	17'-0"	17'-6"	15'-6"	16'-0"	"	A					4'-9½"	4'-9⅜"	**4'-9¼"**	**4'-9⅛"**	**4'-9"**	**4'-8⅞"**	**4'-8¾"**	**4'-8⅝"**	**4'-8½"**	"
		19'-0"	20'-0"	17'-6"	18'-0"	16'-0"		"							4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-9"	4'-8⅞"	4'-8¾"	4'-8½"	"
"G"	"P"	20'-0"	21'-6"	18'-0"	19'-0"			"								4'-9½"	4'-9⅜"	4'-9¼"	4'-9⅛"	4'-8⅞"	4'-8¾"	4'-8⅝"	4'-8½"
	19'-0"	21'-0"	22'-6"	19'-0"				"									4'-9½"	4'-9⅜"	4'-9¼"	4'-9"	4'-8⅞"	4'-8⅝"	4'-8½"
19'-0"		22'-6"						"										4'-9½"	4'-9⅜"	4'-9⅛"	4'-9"	4'-8¾"	4'-8½"

COLUMNS "P" GIVE MAXIMUM WHEEL-BASES FOR PLAIN UNGUARDED CURVES, AND COLUMNS "G" GIVE MAXIMUM WHEEL-BASES FOR GUARDED PORTIONS OF CURVES TO BE OPERATED ON GAGES AND DEGREES OF CURVATURE AS PER TABLE.
WIDTHS OF FLANGE-WAYS FOR GUARDED CURVES AND CURVED CROSSINGS = GAGE MINUS 4'-6¾".

NOTES;

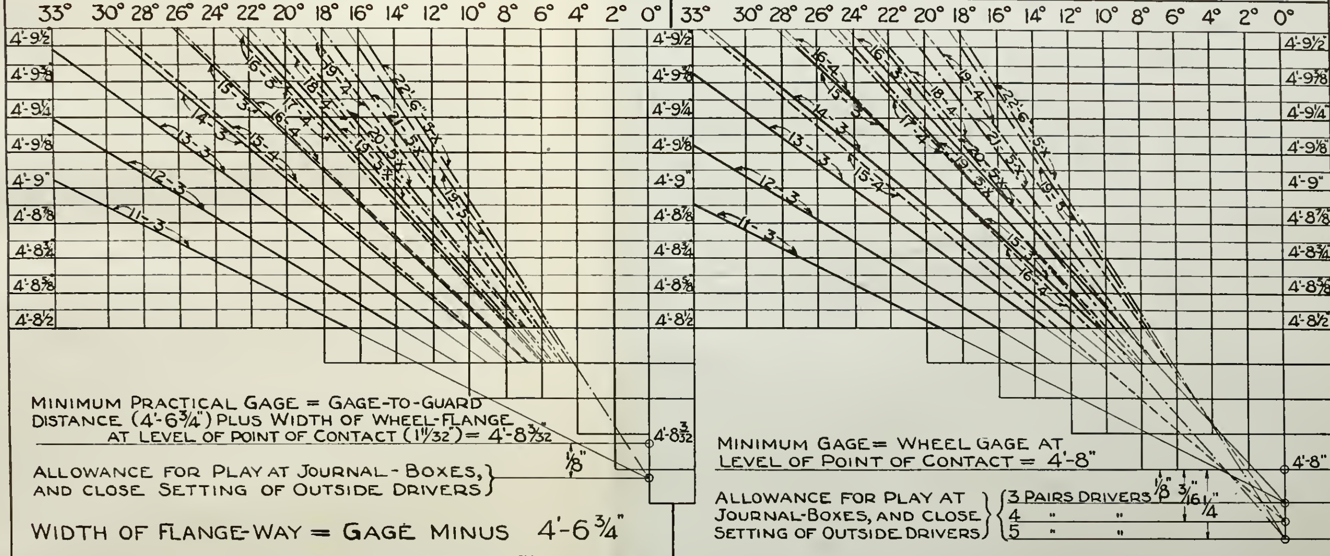
1. APPLICABLE TO LOCOMOTIVIES WITH ONEOR MORE PAIRS OF BLIND CENTER DRIVERS. – "ALL WHEEL BASES" REFERS TO PRACTICAL LIMIT OF APPROXIMATELY 22'6" MEASURED FROM CENTER TO CENTER OF OUTSIDE FLANGED DRIVERS.
2. DRIVERS ON FLOATING AXLES ARE NOT CUNTED AS FLANGED DRIVERS NOR IN THE RIGID WHEEL-BASE.
3. FRONT AND REAR TRUCKS MUST HAVE SIFFICIENT SWING FOR DEGREE OF CURVE, TO OPERATE ON GAGE AND WIDTHS OF FLANGE-WAYS GIVEN.
4. GAGES GIVEN ARE TO THE NEAREST <u>ONE EIGIT INCH</u>, WITH AN ALLOWANCE OF APPROXIMATELY ⅛" FOR 3 PAIRS OF DRIVERS, AND ⅛" TO 3/16" FOR 4 PAIRS, AND ⅛" TO ¼" FOR 5 PAIRS, AS TOTAL (AIN IN LATERAL PLAY AT JOURNAL-BOXES, AND TIGHT SETTING OF OUTSIDE DRIVERS.
5. GAGES AS PER SERIES "A" MAY BE USEDFOR GENERAL CONDITIONS IN MAIN LINE TRACKS UNLESS IT IS KNOWN THAT EXTRA LARGE LOCOMOTIVES OPERATE OVER IT. – GAGES AS PER SERIES "B" MAY BE USED IN YARDS AND SIDINGS WHERE MAIN LINE LOCOMOTIVES DO NOT OPERATE <u>UNLESS OTHERWISE SPECIFIED</u>.
6. FOR GENERAL NEW WORK 4'-9¼" GAGE SHOULD NOT BE EXCEEDED. FOR ECONOMY IN MAINTENANCE IN CURVED CROSSINGS 4'-9" GAGE WITH 2¼" FLANGWAY AND CORRESPONDING CURVATURE SHOULD NOT BE EXCEEDED

SUB-COMMITTEE No 6 - A.R.E.A. TRACK-COMMITTEE V - NOVEMBER, 1921.

GAGES AND FLANGE-WAYS IN CURVED TRACK. TABLE No. 2.

GAGE DIAGRAMS FOR RIGID WHEEL-BASE LOCOMOTIVES

DIAGRAM FOR GUARDED CURVES — DEGREE OF CURVATURE | DIAGRAM FOR PLAIN UNGUARDED CURVES. — DEGREE OF CURVATURE



POSITION OF INTERSECTION BETWEEN DIAGONAL WHEEL-BASE LINE AND VERTICAL DEGREE-LINE WITH REFERENCE TO HORIZONTAL LINES GIVES THE EXACT MINIMUM GAGE REQUIRED. — FOR PRACTICAL GAGES RECOMMENDED SEE TABLE No. 1.

INDICATION ON DIAGONAL LINES OF LENGTH OF WHEEL-BASE AND NUMBER OF DRIVERS:

RIGID WHEEL-BASE IN FEET	NO-FT-3	3	PAIRS, ALL FLANGED DRIVERS.
" " " "	NO-FT-4	4	" " " "
" " " "	NO-FT-5	5	" " " "
" " " "	NO-FT-5-X	5	" CENTER DRIVER BLIND.

FOR OTHER WHEEL-BASES THAN THOSE SHOWN, ADDITIONAL LINES MAY BE INTERPOLATED.

SUB-COMMITTEE No. 6-A.R.E.A. TRACK-COMMITTEE-V- NOVEMBER, 1921

Appendix G

(7) (a) TESTS OF TIE PLATES SUBJECT TO BRINE DRIPPINGS; (b) EFFECT OF BRINE DRIPPINGS ON TRACK APPLIANCES

G. W. HEGEL, *Chairman;*
W. P. WILTSEE,
G. H. BREMNER,
H. G. CLARK,
E. T. HOWSON,
T. T. IRVING,
J. DEN. MACOMB,
F. H. MCGUIGAN, JR.,
J. H. REINHOLDT,
Sub-Committee.

Tie plates were installed in the tracks of the Chicago Junction Railway Company at the Union Stockyards during the months of May, June and July, for the purpose of securing data as to their life under the effect of brine drippings.

These plates were installed on tangent track, where all loaded and iced refrigerator cars from all packing plants are shifted. There is an average of 600 cars daily passing over these tracks, which cars are shifted backward and forward in classifying them, over the track in which these plates are installed. Fully 40 per cent of these cars are refrigerators, and are switched backward and forward several times over these tracks before the entire train is classified.

The two tracks where the tie plates are installed are on an average 18 inches higher than adjacent tracks, and even though stone ballast is used, good drainage cannot be obtained, as there is considerable slime of a greasy nature dripping from these cars, which prevents good drainage.

On account of the traffic as well as the salt brine, it is necessary to renew rails at least once a year, due principally to corrosion.

When the plates were installed, ties were removed when not in good condition and replaced by new ones; joints and rails were renewed, if in poor condition, so that it would not be necessary to disturb the tie plates in making repairs for some time.

Analyses have been made of all plates installed for test, as well as all material used in treating them.

There were 1,329 of these tie plates installed, as follows:

Kinds of Plates	*No. Installed*	*Date Installed*
Malleable iron	150	May 23, 1921
Low carbon	150	May 25, 1921
Wolhaupter soft steel (untreated)	100	June 5, 1921
Wolhaupter copper alloy	100	June 1, 1921
Wrought iron (leadized)	100	June 10, 1921
Wrought iron (untreated)	150	June 15, 1921
Pure iron	79	July 6, 1921
Rolled steel (untreated)	100	July 6, 1921
Rolled steel NO-OX-ID	100	July 6, 1921
Rolled hot tar	100	July 6, 1921
Rolled Texas No. 45	100	July 6, 1921
High carbon	100	July 21, 1921

Besides the above, there are one hundred and seventy-five (175) high carbon plates which are installed in an independent test—one-half untreated and the other half treated with the Texas Company's Carter Grease.

It will be several years before a final report can be made. As these plates have been installed less than one year, the Committee has nothing to report other than progress.

Appendix H

(8) INVESTIGATION ON REDUCTION OF TAPER OF TREAD TO 1 IN 38 AND ON CANTING THE RAIL IN TRACK INWARD

E. A. Hadley, *Chairman;*
W. P. Wiltsee,
J. B. Baker,
R. A. Baldwin,
G. H. Bremner,
H. G. Clark,
E. T. Howson,
T. T. Irving,
F. H. McGuigan, Jr.,
J. B. Myers,
Sub-Committee.

The information which has been secured is so conflicting that it is impossible for the Committee, at this time, to submit a final report and recommendation on this question.

With the thought in mind that the position of the tread of the wheel on the head of the rail would have considerable effect on the rail itself either through internal stresses or by wear on the top or gage side of the rail, and in line with the instruction of the Board of Direction, the co-operation of the Committee on Rail was requested in the consideration of this subject.

The Chairman of the Committee on Rail has appointed a Sub-Committee to go further into this question with Sub-Committee (8) of the Track Committee, but as yet no joint meetings of these two sub-committees have been held.

The Canadian Pacific Railway Company advises, through its Chief Engineer, that they have used tie plates on that railway since 1914 which are inclined to a slope of 1 in 20 and are securing excellent results in so far as the wear on the head of the rail is concerned.

The Pennsylvania System has been experimenting with canting the rail inward as far back as 1907 and a report of this test made in the latter part of 1920 states that some of this rail which was laid canted in 1907 was removed in 1915, the result of the test indicating slightly less wear on the rail than when laid upright, but it was concluded that this was due in that instance to the structure of the steel rather than to the canting of the rail and that gage measurements taken at the time of each inspection throughout the life of the experiment did not indicate any great superiority for this type of track construction; however, it was considered advisable to conduct additional test with tie plates inclined to a slope of 1 in 20.

Reports of these continued tests on the Pennsylvania indicate slightly more wear on rail laid with the inclined plates and that there was practically no difference with regard to cut ties as between the inclined plates and the standard plates which place the rail in practically an upright position.

No special construction of frogs, switches and turnouts with inclined rail was provided in the tests on the Pennsylvania nor are they used in such locations on the Canadian Pacific Railway.

The New York Central Lines have reduced the incline of the wheel tread from 1 in 20, which is the Master Car Builders' Association standard, to an angle of 1 in 38 with a more favorable contour than the present M. C. B. standard.

The Northern Railway of France has recently decided to change its former practice of canting rails and in the future to lay rails in an upright position which has been and is now the practice of the Belgium Railroads.

In view of the fact that the Northern Railway of France has abandoned the general European practice of canting rails and that the railroads of Belgium have never adopted this practice, it would appear that there is a conflict of opinion in Europe as to which method constitutes the best practice. Also, the rather meager information available in the United States on which a definite conclusion can be based, there being but a small percentage of mileage equipped with canted rail, it seems inadvisable at this time to attempt to draw any definite conclusions on this subject.

With new wheel treads and new rail heads, it is, without doubt, possible to procure a more central bearing on the rail, but as they both become worn the position of contact is changed from its position of central bearing, and, due to the more or less flexible track structure, the point of contact on the head of the rails and on the tread of the wheels will vary according to the degree of wear on the majority of the wheels in the trains running over the track in question.

To carry the practice of canting rail to its final theoretical conclusion would require that switches, frogs and turnouts be constructed with inclined rail, as is done in Europe, so that the numerous twists in rail from an inclined to an upright position, in passing through turnouts, might be avoided, but so far as our investigation discloses, no railroads in the United States have yet gone to this extent in their experiments or practice, due to the expense and inconvenience of such special inclined rail construction.

In view of the situation developed to date, it seems advisable that the study of this subject be continued in conjunction with the Rail Committee and with the Mechanical Division of the American Railway Association. It should be possible to arrive at some definite conclusion as to the relation of the tread of the wheels to the rail in a track structure to the end that the most economical and satisfactory practice may be adopted, taking into consideration the relative wear on wheels and rail and the comparative costs of maintenance of track and equipment, both of which must be given proper weight in arriving at the final net financial results.

REPORT OF COMMITTEE IV—ON RAIL

G. J. Ray, *Chairman;*
E. E. Adams,
A. S. Baldwin,
W. C. Barnes,
W. C. Cushing,
Dr. P. H. Dudley,
C. F. W. Felt,
L. C. Fritch,
J. H. Gibboney,
A. W. Gibbs,
C. R. Harding,
J. M. R. Fairbairn, *Vice-Chairman;*
J. D. Isaacs,
H. G. Kelley,
H. D. Knecht,
R. Montfort,
A. W. Newton,
J. R. Onderdonk,
F. S. Stevens,
F. M. Waring,
M. H. Wickhorst,
J. B. Young,

Committee.

To the American Railway Engineering Association:

Your Committee on Rail respectfully submits its report to the Twenty-third Annual Convention:

(1) Revision of Manual

The Committee has been giving consideration to the revision of the specifications for steel rails. It is not ready to report on the subject at this writing but expects to have something to submit on the subject before the time of the convention.

(2) Mill Practice

During the past year the Committee has been devoting considerable attention to the details of the rail manufacturing practices of the several rail mills of the country with reference particularly to the influence they have on the properties of the finished rail. Probably the most important item of manufacture that affects the quality of the finished rail is the condition of the steel as it is poured into the molds. A well-made steel thoroughly deoxidized with silicon or other deoxidizer, sets quietly in the molds with a flat top on the ingot. A steel not fully deoxidized, however, effervesces in the mold and sets with a "horney" top on the ingot. The upper third of an ingot cast with effervescing steel is spongy inside with numerous small holes but with only a small central "pipe." Such steel also shows considerable interior segregation of carbon, phosphorus, and sulphur, resulting in a brittleness in the interior of the head of the upper rail of the ingot. The quiet setting steel is free from interior sponginess, the segregation is much lower and the interior steel of the upper third of the ingot is denser and more ductile, but the ingot has a larger central pipe, which shows as a lamination in the web of the rail lower down from the top of the ingot than in rail made from effervescing steel.

The work by Wickhorst in 1912 (see Proceedings American Railway Engineering Association, Vol. 14, 1913, p. 507), showed that about .25 per cent. or more of silicon is required to obtain its full deoxidizing effect and it would seem that specifications should require a minimum of .20 per cent. silicon in rail steel. In this case the upper end of the A rail, with the usual discard of 10 or 12 per cent., may show a small vertical lamination in the web, but the metal in the head will be free from the sponginess and excessive segregation present in rails made with effervescing steel.

(3) Intensity of Pressure

The Committee has done little work on this subject recently and indeed is puzzled as to suitable procedure to develop exact information concerning it. Several years ago the Committee submitted the results of careful tests of the distortion of small tapered holes drilled into the side of the rail head at various depths from the top surface. It has been suggested that this work might be repeated, but plugging the holes before applying rolling loads to the rail, the thought being that the flow of the metal may have been influenced by the presence of the open spaces. It is rather uncertain, however, that further conclusions could be drawn from a repetition of the work. It may be that additional experimentation should be carried on by the laboratory method, but the cost of the necessary machinery would be considerable and the Committee has not thought it well to bring up at this time the question of financing the work.

(4) Rail Failures

The report on the rail failure statistics for the period ending October 31, 1920, is submitted as Appendix A. The average failures per 100 track miles for all the rails reported on are given below:

Year Rolled	*Years' Service* 0	1	2	3	4	5
1908	...	....	....	.....	.....	398.1
1909	...	....	....	.....	224.1	277.8
1910	...	....	....	124.0	152.7	198.5
1911	...	....	77.0	104.4	133.3	176.3
1912	...	28.9	32.1	49.3	78.9	107.1
1913	2.0	12.5	25.8	44.8	69.5	91.9
1914	1.2	8.2	19.8	32.9	50.9	74.0
1915	0.7	8.9	19.0	34.2	53.0	82.4
1916	1.6	11.8	29.2	47.7	70.6	....
1917	5.3	21.6	38.9	66.0	.....	.....
1918	1.6	8.9	27.6	.....	.....	.....
1919	2.0	14.8	....	.....	.....	.....
1920	3.9	....	....	.....	.....	.....

It will be noted that the failures had been showing a gratifying decrease until the World War came on, even though the conditions of service as to wheel loads had been growing more severe. The "war-time" rollings, however, and particularly the rails rolled in 1917, are not showing up so well. Probably the rail performance record of the next few years will show badly, but after that there is ground for hope that the improvement trend will be again taken up.

(5) Methods of Inspection

The Committee has been giving attention to the methods of inspection of steel rails as used by the different railroads and in Appendix B presents abstracts of the replies to a questionnaire, a discussion of the methods used for the inspection of steel rails and a schedule of Recommended Practice for Inspection of Steel Rails. The Committee recommends that this latter be approved by the Association for inclusion in the Manual.

In Appendix C is submitted a paper by M. H. Wickhorst, on "Formula for Elongation of Rails in the Drop Test," in which is given a formula that has been worked out by which can be calculated the elongation in the drop test for any rail section under given conditions of height of drop and carbon content of the steel, or by which may be calculated the height of drop necessary to produce a given elongation on the first blow for any given rail section and carbon content.

(6) Joint Bar Design

The Committee has nothing to report on this subject this year but expects to give the matter active attention in the future.

(7) Joint Bar Material

The Committee has under consideration tentative specifications for quenched carbon steel track bolts and for quenched alloy steel track bolts. It is expected that these specifications will be put in shape for consideration of the Association at an early date.

(7) Rail Sections

The Committee has been giving attention to the designing of a 150 lb. rail section but is not prepared to report on the matter.

(8) Transverse Fissures

In 1916 a bibliography was presented on the subject of internal fissures in rails (Proceedings, Vol. 17, 1916, p. 587), dating from the beginning of the literature on the subject in 1911 to the end of 1915. In Appendix E, the Committee presents an extended bibliography covering the years 1911 to 1920 inclusive.

The Committee expects to gather full reports of fissure failures on all the railroads for two main purposes:

(1st) To have definite information as to the occurrence and distribution of the failures and to be able to know whether progress is being made from year to year in their elimination.

(2nd) To tabulate and study the reports to determine the relationship of the various manufacturing and service conditions to the failures.

For the first purpose a summarized report should be made periodically, say once a month or once a quarter. For the second purpose selected data sufficiently extensive should be used but after the relationships have been fully established, the special tabulations may be discontinued.

Conclusions

The Committee recommends that the schedule of recommended practice for the inspection of steel rails, submitted in Appendix B, be adopted and included in the Manual.

Subjects for Future Work

Your Committee recommends that the following subjects be assigned to it for 1922.

1. Study the Manual and submit proposed revisions thereof.
2. Continue the study and report on details of manufacture and mill practice as they affect rail quality.
3. Continue the study and report on the rational relation between intensity of pressure due to wheel loads and resistance of various rail steels to crushing and deformation.
4. Study and report a fair and correct method of reporting rail failures.
5. Continue the study and report on the developments in methods of rail inspection.
6. Recommend designs of rail joints and bolts covering important dimensions affecting interchange of both.
7. Continue the study and report on material for track bolts and joint bars and methods of treatment.
8. Continue the study and recommend sections for rails over 140 lb. per yd.
9. Continue the study of transverse fissures, with special reference to cause and elimination thereof.
10. Report on the most desirable length of rails.
11. Recommend a carefully considered outline of work for the ensuing year.

Respectfully submitted,

THE COMMITTEE ON RAIL,

G. J. RAY, *Chairman.*

Appendix A

RAIL FAILURE STATISTICS FOR 1920

By M. H. Wickhorst

This report deals with the statistics of rail failures collected for the year ending October 31, 1920, furnished by the railroads of the United States and Canada, in response to a circular sent out by the American Railway Association. The information furnished by each railroad showed the number of tons of each year's rolling from each mill, the equivalent number of track miles, and the total number of failures that occurred in each year's rolling from the date laid until October 31, 1920.

They were reported by the railroads on American Railway Engineering Association form 408 as revised in 1915. (See Manual for 1915, page 104.) The report covers rollings for 1915 and succeeding years and the ages of the rolling would average in track about the years shown below:

1915—5 years	1918—2 years
1916—4 years	1919—1 year
1917—3 years	1920—several months

The tonnages and track miles of rail represented by the statistics in this report are as follows:

Year Rolled	*Tons*	*Track Miles*
1915	1,091,876	7,346.50
1916	1,193,905	8,062.10
1917	1,096,395	7,334.40
1918	990,820	6,658.80
1919	989,398	6,676.60
1920	759,071	5,064.20
Total..............	6,121,465	41,142.60

In previous years the detail results as given by the railroads have been presented, arranged and classified by the mills that made the rails, and for the last two years they were also classified by the railroads that used them. In the present report, however, on account of a desire to save the expense of preparing the detail statements and to reduce the amount of printing, only the general average results are presented.

Lots of less than 1,000 tons (that is, less than 1,000 tons in any one year's rolling for a railroad) were excluded from the tabulations, as they would not materially change the group totals and averages and would unnecessarily extend the tables and increase the work. The method of compiling the statistics was to make blueprints of the reports submitted by the different railroads after checking the calculations and seeing that all the lines were fully filled out, and then cutting the prints along the horizontal lines. The strips constituted the units in the tables, and were sorted and collected into the desired groups for which the totals and averages were calculated.

The average results of all the rails reported on are shown in Table 1, together with the results taken from previous reports including both bessemer and open-hearth rails. The measure of the performance of a lot of rails as regards failures is taken as the failures per hundred track miles for five years' service and it will be noted that there was a continuous decrease in the failures from the rails rolled in 1908 with a record of 398.1 to those rolled in 1914 with a record of 74.0. The rails rolled in 1915 showed an increase to 82.4 failures per 100 track miles for five years' service and a study of the records for lesser periods of service indicates, that the rails rolled in 1916 and 1917 will show successively increased numbers of failures. This unfortunate performance is probably to be regarded as a by-product of the war and the manufacturing conditions that prevailed during the war and for a while thereafter. Under-maintenance during the same period probably contributed to increase the general failure records, but it is to be noted that the 1914 rails, which have given the best record, also went through the same period of under-maintenance.

The general average results for the whole country are presented diagrammatically in Fig. 1. Here again will be noted how the failure curve showed continuous decrease in failures until the present year which shows an increase. The curve will acquire an ugly hump which we hope will reach its peak in the record of the 1917 rails. The same information for each of the mills is shown in Fig. 2.

A summary from eight years' reports showing the track miles and total failures in addition to the failures per 100 track miles shown in Table 1, are presented in Table 2. The average results of the rails from each of the mills for the rollings since 1908 are given in Table 3. These tables are the records for open hearth rails, except that for the last two years, the few bessemer rails that were made are also included. It will be noted that the rails from most of the mills showed a progressive decrease in failures since the records were started, although in recent years some poor showings are made in a few cases. The failures in the rollings from each of the mills from 1915 to 1919 inclusive are shown diagrammatically in Figure 3.

Another summary sheet is presented in Table 4 which shows the performance of the rails rolled at each of the mills in recent years. The special feature of this table is that the failures per 100 track miles are also shown per year of service and an average shown for the rollings from 1915 to 1919 inclusive for each mill. These average results are presented diagrammatically in Figure 4. On this basis the lowest failure per 100 track miles per year were from the Colorado rails with a figure of 11.15 and the next lowest were from the Carnegie rails with 12.28.

Lastly, as interesting information, the average weight of the rails rolled at each of the mills is presented in Table 5.

In conclusion it may be remarked that the failures had been showing a gratifying decrease from year to year until the World War came on. The "war-time" rollings, however, and particularly the rails rolled in 1917, are not showing up so well, due probably to the unfavorable manufacturing conditions that prevailed when they were made and also to the lack of the usual care in the track that the railroads were able to give them during the same period. That the unfavorable manufacturing conditions were the more important factor is indicated by the good performance of the 1914 rails, which is the best so far attained in spite of the fact that these rails also were subject to the same conditions of under-maintenance. It should now be the aim and effort of all concerned to again bring about a continued reduction in the rail failures. Although we will have a bad failure record for a few years in the immediate future as one of the many unwelcome heritages of the war, still it is entirely practicable and feasible to reduce the rail failures below the best performance so far attained, while at the same time getting an increased resistance to wear and thus lengthening the life of rails.

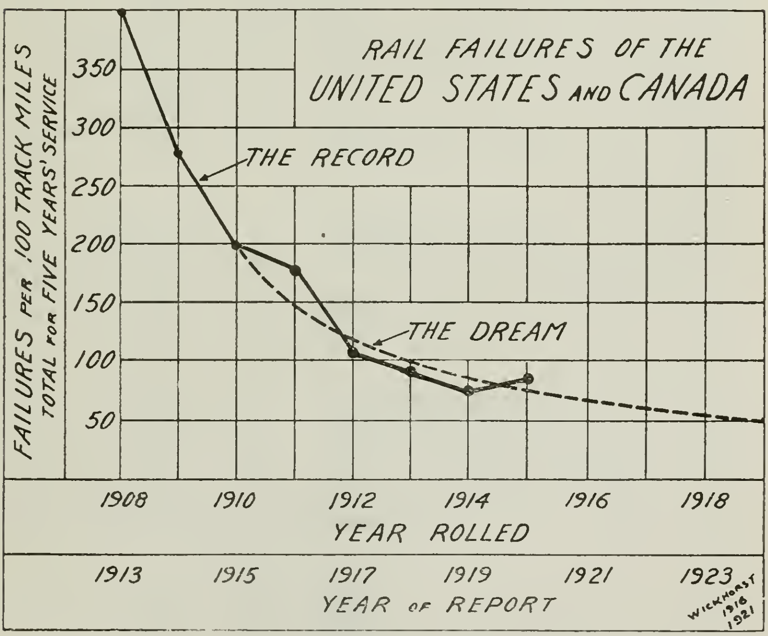


FIG. 1.

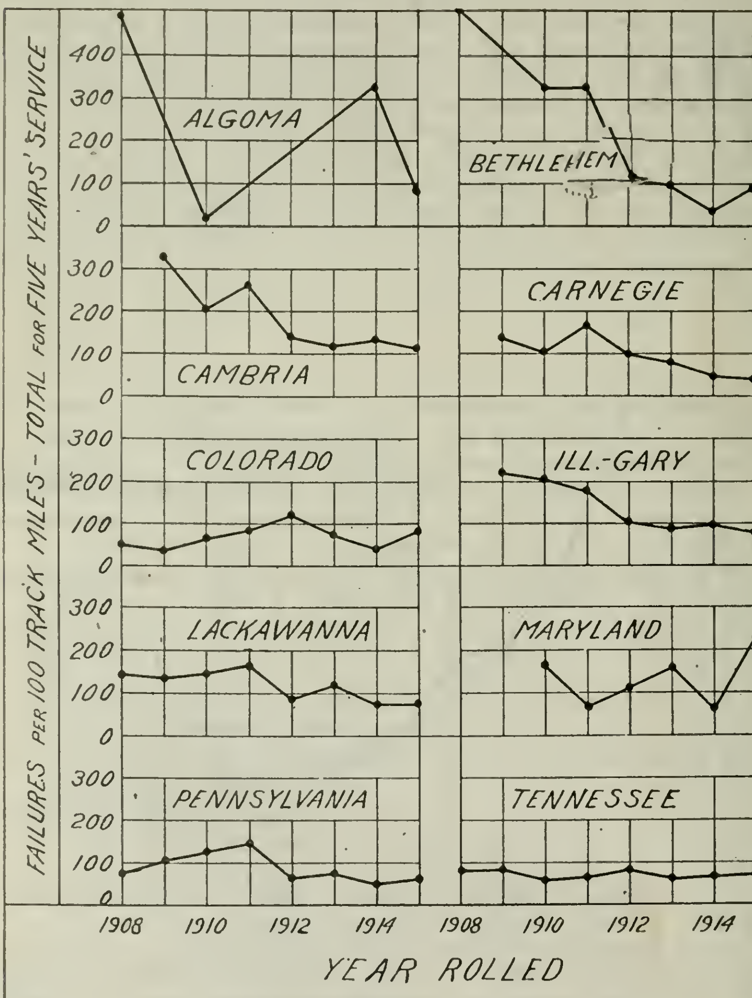


Fig. 2. Average Results for Each Mill.

DIAGRAM SHOWING FAILURES PER 100 TRACK MILES BY MILLS AND YEARS

FOR PERIOD ENDING OCTOBER 31, 1920.

Mill	Year Rolled	Failures Per 100 Trk Mls
ALGOMA	1915	84.0
	1916	96.8
	1917	9.1
	1919	7.3
BETHLEHEM	1915	92.4
	1916	110.9
	1917	94.8
	1918	57.7
	1919	31.2
CAMBRIA	1915	111.5
	1916	73.7
	1917	112.9
	1918	95.5
	1919	33.3
CARNEGIE	1915	43.7
	1916	45.6
	1917	39.3
	1918	41.6
	1919	8.5
COLORADO	1915	80.3
	1916	53.6
	1917	38.7
	1918	13.1
	1919	5.0
DOMINION	1918	60.1
	1919	5.7
ILLINOIS	1915	78.8
	1916	70.7
	1917	46.3
	1918	10.8
	1919	11.5
LACKAWANNA	1915	73.1
	1916	58.0
	1917	46.6
	1918	23.7
	1919	22.8
MARYLAND	1915	231.4
	1916	96.6
	1917	360.5
	1918	59.2
	1919	34.2
PENNSYLVANIA	1915	59.6
	1916	136.1
	1918	9.2
	1919	46.9
TENNESSEE	1915	70.9
	1916	82.4
	1917	58.2
	1918	34.6
	1919	14.1
GEN'L AVER. ALL MILLS	1915	82.4
	1916	70.6
	1917	66.0
	1918	27.6
	1919	14.8

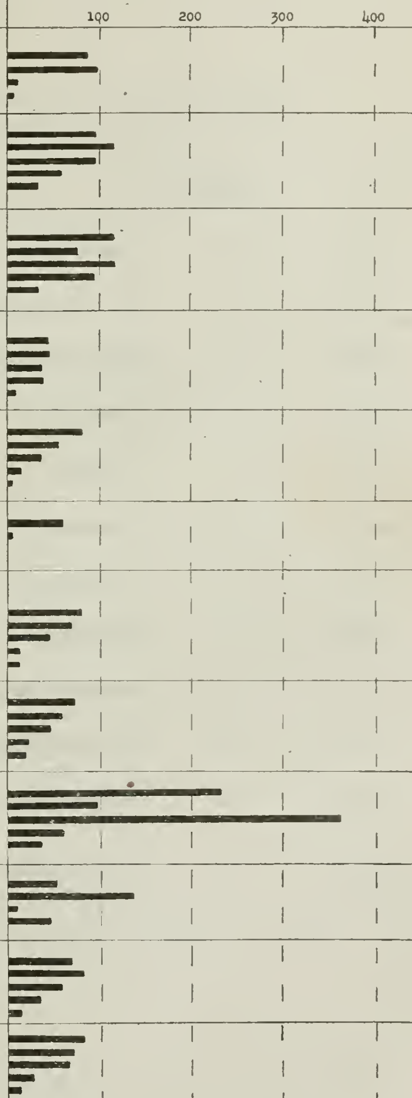


FIG. 3. ACCUMULATED FAILURES FOR ROLLINGS FROM 1915 TO 1919.

DIAGRAM SHOWING FAILURES PER 100 TRACK MILES PER YEAR BY MILLS

FOR PERIOD ENDING OCTOBER 31, 1920.

Mill	Failures Per 100 Trk Mls Per Year
ALGOMA	14.85
BETHLEHEM	27.68
CAMBRIA	27.84
CARNEGIE	12.28
COLORADO	11.15
DOMINION	15.36
ILLINOIS	13.20
LACKAWANNA	15.48
MARYLAND	49.81
PENNSYLVANIA	22.10
TENNESSEE	17.31
GEN'L AVER. ALL MILLS	17.01

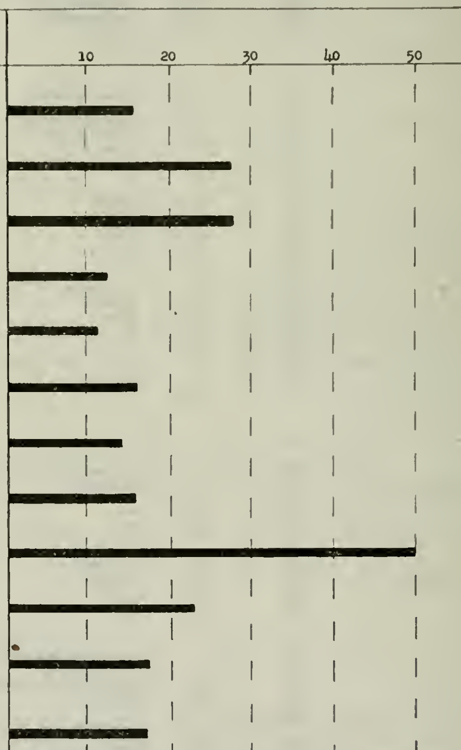


FIG 4. AVERAGE FAILURES CLASSIFIED BY MILLS FOR THE ROLLINGS FROM 1915 TO 1919, INCLUSIVE.

TABLE 1- AVERAGE FAILURES PER 100 TRACK MILES

Year Rolled	Years Service					
	0	1	2	3	4	5
1908	-	-	-	-	-	398.1
1909	-	-	-	-	224.1	277.8
1910	-	-	-	124.0	152.7	198.5
1911	-	-	77.0	104.4	133.3	176.3
1912	-	28.9	32.1	49.3	78.9	107.1
1913	2.0	12.5	25.8	44.8	69.5	91.9
1914	1.2	8.2	19.8	32.9	50.9	74.0
1915	0.7	8.9	19.0	34.2	53.0	82.4
1916	1.6	11.8	29.2	47.7	70.6	-
1917	5.3	21.6	38.9	66.0	-	-
1918	1.6	8.9	27.6	-	-	-
1919	2.0	14.8	-	-	-	-
1920	3.9	-	-	-	-	-

Table 2

SUMMARY FROM EIGHT YEARS REPORTS SHOWING TRACK MILES, TOTAL FAILURES AND FAILURES PER 100 TRACK MILES

Service	Five Years			Four Years			Three Years			Two Years			One Year			Several Months		
	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls	Trk Mls of Rail Laid	Failures Total	Failures Per 100 Trk Mls
From 1913 Report																		
Year Rolled		1908			1909			1910			1911			1912			1913	
Totals-	3201.35	12746	398.1	6340.54	14208	224.1	9860.18	12227	124.0	6536.05	5030	77.0	7105.74	2050	28.9	5848.64	118	2.0
From 1914 Report																		
Year Rolled		1909			1910			1911			1912			1913			1914	
Totals-	6697.39	18605	277.8	10024.85	15309	152.7	6096.48	6354	104.4	7610.60	2431	32.1	8775.44	1095	12.5	4768.34	56	1.2
From 1915 Report																		
Year Rolled		1910			1911			1912			1913			1914			1915	
Totals-	11587.43	22981	198.5	7980.75	10635	133.3	10374.18	5119	49.3	10668.59	2756	25.8	7061.24	584	8.2	4286.26	31	0.7
From 1916 Report																		
Year Rolled		1911			1912			1913			1914			1915			1916	
Totals-	7969.41	14052	176.3	10260.93	8100	78.9	11335.41	5076	44.8	7505.24	1483	19.8	7381.29	656	8.9	5352.71	87	1.6
From 1917 Report																		
Year Rolled		1912			1913			1914			1915			1916			1917	
Totals-	10778.68	11546	107.1	12526.60	8706	69.5	7819.79	2576	32.9	7344.65	1395	19.0	8532.53	1004	11.8	4713.76	251	5.3
From 1918 Report																		
Year Rolled		1913			1914			1915			1916			1917			1918	
Totals-	11883.57	10924	91.9	7752.27	3948	50.9	7072.23	2414	34.2	8347.44	2439	29.2	7384.26	1596	21.6	3262.43	53	1.6
From 1919 Report																		
Year Rolled		1914			1915			1916			1917			1918			1919	
Totals-	7917.26	5855	74.0	7280.51	3862	53.0	8407.55	4013	47.7	7615.46	2962	38.9	6354.44	568	8.9	4272.95	85	2.0
From 1920 Report																		
Year Rolled		1915			1916			1917			1918			1919			1920	
Totals-	7346.50	6057	82.4	8062.10	5691	70.6	7334.40	4844	66.0	6658.80	1837	27.6	6676.60	986	14.8	5064.20	197	3.9

FAILURES FOR VARIOUS AGES OF RAIL PER 100 TRACK MILES Table 3

Year Rld	Years Service 0	1	2	3	4	5	Years Service 0	1	2	3	4	5
	Algoma						**Bethlehem**					
1908						482.9						503.7
1909					203.7						466.1	
1910				431.0		13.8				174.0	245.0	330.9
1911			219.7						113.3	195.3	251.7	329.8
1912		124.0						11.9	32.0	52.1	83.2	106.8
1913							1.6	13.4	26.9	52.6	77.3	99.5
1914		19.0	43.2	67.1	67.9	321.4	0.0	3.8	6.9	16.0	21.6	33.0
1915	1.4	7.1	11.8	22.9	39.1	84.0	0.0	17.1	24.5	41.0	65.0	92.4
1916	4.3	22.7	42.1	63.4	96.8		4.5	17.7	42.5	75.2	110.9	
1917	135.5	2.0	2.0	9.1			12.1	39.0	59.2	94.8		
1918							11.0	19.6	57.7			
1919		7.3					3.1	31.2				
1920	0.0						0.8					
	Cambria						**Carnegie**					
1908												
1909					244.8	326.6					104.1	137.1
1910				98.5	136.4	201.0				98.9	112.9	101.1
1911			73.7	126.1	227.7	257.2			71.5	108.9	123.1	165.6
1912		17.1	41.8	74.3	108.9	140.9		12.3	30.9	55.3	78.4	98.8
1913	7.1	26.7	49.5	78.3	106.2	120.1	2.5	8.9	19.4	33.8	62.9	80.8
1914	1.7	15.8	37.7	61.9	64.3	137.7	0.8	5.5	11.9	16.6	25.4	48.8
1915	1.0	6.3	19.5	34.1	58.7	111.5	0.3	1.8	8.6	16.9	29.2	43.7
1916	5.4	7.3	25.9	33.7	73.7		0.4	4.9	13.2	26.8	45.6	
1917	14.3	23.9	38.9	112.9			1.5	6.1	19.5	39.3		
1918	0.0	32.9	95.5				1.4	6.2	41.6			
1919		33.3					1.6	8.5				
1920	16.9						2.9					
	Colorado						**Dominion**					
1908						45.5						
1909					22.4	34.2						
1910				19.6	23.4	60.9						
1911			15.8	31.0	52.6	84.3						
1912		18.3	40.9	55.6	91.3	117.6						
1913	1.2	3.9	11.0	26.0	46.6	82.1						
1914	1.0	3.7	7.6	14.1	27.3	42.0						
1915	0.2	4.6	7.7	15.1	34.4	80.3						
1916	1.0	5.8	15.7	34.5	53.6							
1917	0.7	5.4	12.5	38.7								
1918	0.0	6.5	13.1						60.1			
1919	1.9	5.0						5.7				
1920	0.7						0.0					
	Illinois						**Lackawanna**					
1908												143.5
1909					151.9	219.7					100.1	117.8
1910				88.4	136.8	206.2				42.7	90.3	148.9
1911			67.5	94.0	107.7	178.6			29.5	57.1	108.6	162.5
1912		7.4	23.2	39.2	64.6	100.0		4.8	20.1	39.6	67.1	88.6
1913	1.1	10.0	21.9	44.0	62.1	91.5	2.3	17.2	31.4	51.9	74.0	115.3
1914	1.0	11.6	30.0	47.3	83.6	98.3	0.3	1.8	10.0	24.5	49.3	78.7
1915	0.1	10.7	21.9	40.9	56.1	78.8	0.2	10.5	23.8	38.1	57.3	73.1
1916	0.8	11.1	26.0	43.9	70.7		2.4	8.9	25.5	40.1	58.0	
1917	0.7	9.1	19.9	46.3			0.8	16.8	31.6	46.6		
1918	0.2	2.5	10.8				2.1	7.4	23.7			
1919	0.6	11.5					2.5	22.8				
1920	0.9						5.1					
	Maryland						**Pennsylvania**					
1908												72.8
1909											86.3	101.4
1910				69.6	104.8	163.7				81.4	110.9	123.8
1911			32.9	49.5	58.5	67.4			34.6	79.6	119.0	145.2
1912		11.3	5.8	18.1	8.6	110.8		5.3	15.6	27.5	46.8	60.4
1913	0.9	28.6	74.1	88.4	117.0	159.7	1.1	9.8	21.0	34.7	47.2	71.2
1914	1.1	13.3	25.2	31.5	36.2	62.9	2.5	8.2	21.1	29.4	38.0	49.7
1915	8.3	24.5	60.2	99.6	138.1	231.4	0.0	6.3	18.1	27.9	48.4	59.6
1916	1.6	30.7	61.8	92.6	96.6		0.0	35.6	46.1	94.2	136.1	
1917	49.1	160.5	214.2	360.5			0.0					
1918	6.9	23.7	59.2					2.4	9.2			
1919	10.8	34.2					11.1	46.9				
1920	0.0						1.8					
	Tennessee						**All Mills**					
1908						86.5						370.5
1909					11.1	83.7					163.6	198.5
1910				32.4	47.8	55.2				81.3	107.1	154.0
1911			14.9	25.1	40.8	61.7			53.0	83.5	111.2	161.9
1912		7.3	32.9	43.9	64.5	83.2		26.3	28.9	46.0	74.2	102.7
1913	1.5	5.7	16.5	24.5	41.6	57.3	1.8	11.5	24.8	43.3	68.5	90.3
1914	1.7	7.5	16.6	29.0	44.2	60.8	1.1	7.9	18.9	30.8	47.4	74.0
1915	1.3	6.0	16.0	30.5	48.0	70.9	0.8	8.8	19.0	33.8	53.0	82.4
1916	2.3	15.6	37.1	61.1	82.2		1.7	11.7	27.9	47.7	70.6	
1917	3.2	17.3	35.7	58.2			5.4	21.8	38.9	66.0		
1918	1.6	16.4	34.6				1.5	8.9	27.6			
1919	2.2	14.1					2.0	14.8				
1920	12.1						3.9					

Table 4

RECAPITULATION - TOTALS AND AVERAGES GROUPED BY MILLS

Year	Track Miles	Failures to Date Total	Per 100 Track Miles To Date	Per 100 Track Miles Per Year	Track Miles	Failures to Date Total	Per 100 Track Miles To Date	Per 100 Track Miles Per Year
	Algoma				Bethlehem			
1915	457.86	385	84.0	16.80	529.06	489	92.4	18.48
1916	141.56	137	96.8	24.20	482.12	535	110.9	27.72
1917	43.73	4	9.1	3.03	527.50	500	94.8	31.60
1918					365.76	211	57.7	28.85
1919	151.49	11	7.3	7.30	669.04	209	31.2	31.20
Totals	794.64	537		14.85	2573.48	1944		27.68
	Cambria				Carnegie			
1915	391.87	437	111.5	22.30	740.45	324	43.7	8.74
1916	425.86	314	73.7	18.42	786.70	359	45.6	11.40
1917	329.55	372	112.9	37.63	664.58	261	39.3	13.10
1918	179.93	170	95.5	47.75	499.43	208	41.6	20.80
1919	63.07	21	33.3	33.30	467.61	40	8.5	8.55
Totals	1390.28	1314		27.84	3158.77	1192		12.28
	Colorado				Dominion			
1915	1103.30	886	80.3	16.06				
1916	1162.66	623	53.6	13.39				
1917	988.58	383	38.7	12.90				
1918	871.96	114	13.1	6.55	159.78	96	60.1	30.05
1919	936.11	47	5.0	5.02	243.65	14	5.7	5.74
Totals	5062.61	2053		11.15	403.43	110		15.36
	Illinois				Lackawanna			
1915	1905.77	1502	78.8	15.76	768.57	562	73.1	14.62
1916	2495.85	1764	70.7	17.67	987.10	573	58.0	14.51
1917	2006.39	929	46.3	15.43	935.71	436	46.6	15.53
1918	2169.35	235	10.8	5.41	864.51	205	23.7	11.85
1919	2144.81	247	11.5	11.51	586.24	134	22.8	22.80
Totals	10722.17	4677		13.20	4142.13	1910		15.48
	Maryland				Pennsylvania			
1915	287.61	665	231.4	46.28	152.69	91	59.6	11.92
1916	416.07	402	96.6	24.15	47.75	65	136.1	34.02
1917	294.00	1060	360.5	120.16				
1918	295.39	175	59.2	29.60	43.40	4	9.2	4.60
1919	194.54	66	34.2	34.23	74.52	35	46.9	46.90
Totals	1487.61	2368		49.81	318.36	195		22.10
	Tennessee				All Mills			
1915	1009.30	716	70.9	14.18	7346.50	6057	82.4	16.48
1916	1116.43	919	82.3	20.57	8062.10	5691	70.6	17.65
1917	1544.41	899	58.2	19.40	7334.40	4844	66.0	22.00
1918	1209.42	419	34.6	17.30	6658.80	1837	27.6	13.80
1919	1145.75	162	14.1	14.10	6676.60	986	14.8	14.80
Totals	8025.31	3115		17.31	36078.4	19415		17.01

Table 5

AVERAGE WEIGHTS OF RAILS

COMPILED FROM TONNAGES USED IN THIS REPORT

Mill	1915	1916	1917	1918	1919	1920
Algoma	90.1	90.1	85.0		94.2	101.7
Bethlehem	98.6	99.2	103.0	104.3	109.3	120.3
Cambria	102.5	103.4	118.4	118.9	112.1	130.0
Carnegie	98.8	100.7	100.2	104.1	105.6	101.7
Colorado	89.8	89.0	90.4	90.3	89.7	90.5
Dominion				85.0	85.0	
Illinois	93.3	92.9	92.9	93.3	92.1	93.5
Lackawanna	96.7	94.9	97.1	95.3	95.2	96.1
Maryland	104.4	102.8	106.7	104.2	93.6	85.0
Pennsylvania	104.6	102.0		100.0	101.2	103.0
Tennessee	88.1	88.5	87.9	88.3	89.1	88.6
Average	94.6	94.3	95.1	96.1	94.2	95.4

Appendix B

RAIL INSPECTION

Recommended Practice for Inspection of Steel Rails

I. Inspection Force

1. Chief Rail Inspector.
2. Three or more assistant inspectors as size of mill and rate of rolling may require.
3. One or more checkers, depending upon rapidity of loading.
4. One chemist if check analyses are made in mill laboratory.

II. Duties of Inspectors

1. The Chief Rail Inspector shall supervise the inspection force, mill practice, drop tests and make records.

2. One assistant inspector shall follow the mill practice closely, i. e., time of charging, time of tapping, cutting of tests, etc.; record any irregularities, such as too rapid pouring, charging cold ingots, rolling cold bloom, low finishing temperature, behavior of rails under straightening presses or any other departures from good mill practice which may affect the service of the rails.

3. One assistant inspector for night duty shall make drop tests if necessary and follow the mill practice.

4. One or more assistant inspectors shall inspect the rails on the loading beds for surface defects, straightness, etc.

5. One or more checkers shall record the number of rails of each heat accepted and loaded in each car. A record of the car number and the number of rails of each heat in the car shall be sent to the Division Engineer, the Supervisor, the Roadmaster or other officer to whom the rails are consigned.

This prevents the loading of rails rolled from odd ingots, or the loading of more rails than were originally rolled in a heat, or the loading of rails from rejected heats. It also furnishes a check record of the location of the rails if at any time in the future it is desired to remove the rails of a particular heat for any cause whatever.

6. A chemist shall make check analysis of drillings taken from corner of head of the rail, no rails being loaded until the check analysis is finished.

The office to which the rail inspection force reports should keep a record of the history of each heat in a convenient form, so the results obtained from the service of the rails may be traced to the manufacture of the steel or rails.

Rail inspectors should be selected with care and men not familiar with rolling mill practice should not be sent to inspect rails except under the supervision of an experienced rail inspector. As far as possible the inspections should be made by the same men, as they then become familiar with the methods of manufacture peculiar to each mill, for no two mills follow the same procedure even though owned by the same company.

Acceptance of heats meeting the technical requirements of specifications, but in the judgment of the inspector of inferior quality should be deferred pending decision of Engineer of Tests after full report and review of conditions; conversely, rejections of heats whose deficiencies may be technical only should be similarly governed.

The inspectors cannot be too careful and must exercise good judgment and all possible tact.

Methods of Inspection of Steel Rails

For the purpose of gathering information concerning the methods of inspecting rails used by the different railroads, the Chairman of the Sub-Committee sent out a questionnaire to the large railroads asking for information as to their inspection practices. Below are given copies of the letter and the questionnaire sent out, a discussion of the several items, recommendations, and abstracts of the replies received.

Letter and Questionnaire

Letter:

"The Committee on Rail of the American Railway Engineering Association desires to gather information concerning the methods used by the various railroads in the inspection of steel rails. The Committee proposes to study and tabulate the replies and finally submit recommendations as to the methods of rail inspection and organization of inspection staffs. The more full and complete the returns to the questionnaire, the more valuable to the Railroads are the Committee's recommendations apt to be, and you are therefore asked to kindly submit a reply to each of the questions on attached questionnaire, writing and commenting fully on each subject.

In case you do not handle the inspection of rails, kindly refer this matter to the officer in charge."

Questionnaire:

1. Describe your inspection organization.
2. Describe the duties of each of the inspectors.
3. Describe selection of samples for chemical analyses, including ladle test, rail analyses, and check analyses.
4. Describe arrangements for making analyses.
5. Describe selection of samples for drop test or other physical tests of rails.
6. Describe method and instruments used to determine the deflection of rails.
7. Describe method and instruments used to determine the elongation of rails.
8. Describe the methods used for the surface inspection of rails.
9. Describe what records are kept of the details of manufacture of the rails.

10. Describe method for making sure that there is no error in shipping the rails which are tested and inspected, and that no odd ingots from other heats get mixed in with the accepted ones under the same heat numbers.
11. Other comments and suggestions.
12. Submit a sample of each of the forms used in connection with rail inspection reports.

Discussion

Below are given discussions of the several items considered under the general subject of rail inspection.

Inspection Organization and Duties of Inspectors.

The organization for inspecting rail and the kinds of inspection made differ on the several railroads. All roads make a final surface inspection to classify the rails into No. 1, No. 2 and rejects, and they also all use the drop test for making physical tests of samples of the rails. Some roads keep a record of all details of manufacture including the making of the steel, giving special attention to irregularities. Others make analyses of the finished rails for the purpose of checking the heat analyses or as an acceptance test. These analyses may be made by the railroad chemists in the mill laboratory or in the railroad laboratory.

In general the inspection organization should consist of the Chief Inspector in charge at the mill, one day and one night drop test inspector, two surface and loading inspectors and such other inspectors and chemists as needed throughout the mill and to make analyses as required by the specifications or the contract.

Chemical Analyses.

Most of the railroads accept the heat analyses as delivered to them by the mills. In some cases drillings from the ladle test ingot are sent to the railroad's laboratory and occasional check analyses made for information. Drillings from rails, taken by the inspector, are also sometimes sent to the railroad laboratory for check analyses. Two of the roads send chemists to the mill to make analyses of samples from the rails, using the mill facilities. The analyses of the rails are made to determine the average composition of the steel.

Several years ago the Pennsylvania made a chemical "segregation test" on some of its rails by comparing samples from the corner of the head ("o" or outside position) and the interior of the head ("m" or middle position), requiring the carbon in the m position to not exceed that in the o position by more than a specified amount. A chemical laboratory car with a staff of chemists was sent to the mills to make the analyses.

The heat analysis generally represents fairly closely the average steel as contained in the rails but occasionally the discrepancy is large, and in the case of rails for the more important service, acceptance should probably be based upon the analysis of the finished rails instead of upon the analysis of the heat sample.

Samples for Drop and Other Physical Tests.

Samples for the drop tests are uniformly taken from the second, middle and last full ingot of each heat, from the top end of the rail bar above the A rail. In the case the A rails are rejected, it is permitted to take the sample for further test from the bottom of the A rail in lieu of the top of B rail. To some extent the "nick and break" test on every ingot is used, by noting the fracture of a small piece from the top end of the rail bar. If it shows a defect or "segregation" the A rail of that ingot is rejected. Tensile tests are used somewhat, for information.

Several years ago the Pennsylvania made tests with a "quick bend" tester or hydraulic bending machine. The results were much the same as with the drop test but the hydraulic bender probably has several advantages. A rail is bent either in the drop test machine or hydraulic bender to test the ductility of the part in tension. In the drop machine with either the head or base in tension, some of the breaks are abnormal due to the splitting of the flange, but in the hydraulic bender normal breaks are always obtained by the exhaustion of the tensile ductility. With the hydraulic bender, an automatic load deflection diagram can be obtained. And further a large number of tests could probably be made several times faster in the hydraulic bender than in the drop machine.

Deflection.

The usual method of determining the deflection or set of the rail after a blow in the drop machine is to lay a 3-ft. straight edge on the inside of the bend and measure the ordinate from the straight edge to the rail where struck by the tup. The steel scale used generally slides in a slot and is graduated into hundredths, fiftieths, or perhaps tenths of an inch. This direct measurement of the deflection includes also the local indentation of the tup which is a variable amount but averages about .10 inch for the first blow. In order to exclude the local indentation from the measurement, Hunt & Co. uses a gage by which the deflection is measured from the outside of the bend. The gage consists of a bar with two arms at the end of the bar at right angles to it and spaced three feet apart. One form of such a deflection gauge was illustrated in the Proceedings of the American Railway Engineering Association for 1911, Vol. 12, Part 2, page 531.

Elongation.

For measuring elongation it is the uniform practice to mark the part to be tested in tension, on the longitudinal center line, with gage marks one inch apart for three inches each side of the center of the specimen. The marking is usually done with a gang of seven prick punches. The elongation is usually measured by means of a flexible steel scale graduated into hundredths of an inch. A more accurate method used somewhat is to gage the elongated space with a pair of fine pointed toolmaker's dividers and then lay this off on the scale.

This method of determining the ductility of the rail is one that was devised by Dr. P. H. Dudley and used by him in 1891 at the plant of the Bethlehem Steel Company, and its adoption marks one of the notable advances in the art of rail inspection.

The practice is divided between testing with the head in tension and with the base in tension. The original method was to test with the base in tension (that is, base down), but the work of the Rail Committee early showed that more information as to the interior condition of the rail is obtained with the head in tension, and its results more nearly correlate with the interior segregation of carbon and phosphorus. The testing with the head down is a better safeguard against failures such as split heads and horizontal fissures, and probably also against transverse fissures, than the testing with the base down, and rails should therefore be tested with the head down.

Surface Inspection.

The practice as regards the surface inspection of rails seems to be much the same on all railroads. Its purpose is to classify the rails into No. 1 and No. 2, with an occasional rejection on account of excessive defectiveness of surface. In general the rails are "walked" on four sides, they are examined for straightness, the drilled holes examined for pipes and correctness of drilling, the heat numbers checked and the loading supervised. To some extent the harder or softer rails are kept separate in loading. The Southern Railway has the front ends of all rails milled in order to better detect the presence of pipes.

Records of Manufacture.

Most of the roads keep only general records of the details of manufacture or not any. The inspection by Hunt & Co. includes the placing of inspectors to observe and record the details of manufacture beginning with the making of the steel in the open-hearth or bessemer plant, giving especial attention to any irregularities.

Checking Against Errors.

Reliance is generally put upon the mills whose procedure is usually satisfactory, but sometimes count is kept of the ingots poured and the blooms and rails made from each heat.

Recommendations.

The inspection procedure will vary somewhat according to the requirements of the specifications and the needs of the road, and in general the inspection methods of most roads are satisfactory. There is one important matter, however, in which the inspection procedure of a number of the roads should be changed; namely, as to the part of the rail which is put in tension in the drop test. As explained under the subject "Elongation," testing the rail with the head down is a better safeguard against obtaining rails subject to failures such as split heads and transverse fissures, and it should therefore be the practice of all roads to test the rails with the head down.

For the reasons given under the subject of drop and other physical tests, the hydraulic method of bending the rail seems to be preferable to the bending of it in the drop machine and the roads should give active consideration to its use.

Abstract of Replies

1. Inspection Organization.
2. Duties of Inspectors.

Baltimore & Ohio.

Inspection staff consists of six men; one in charge supervises mill operations, checks sections and shearing, two drop test men, one day and one night, two make surface inspection on loading beds, one checks drillings, pipes and straightness.

Canadian Pacific.

Inspectors supplied by Robert W. Hunt & Co. Day and night inspectors in open-hearth, blooming mill, on section, on drop test and final inspectors.

Chicago, Rock Island & Pacific.

Rail inspection done by testing department in charge of Engineer of Tests, who has a Chief Inspector, who in turn has a Chief Rail Inspector. The Chief Inspector checks rail section and weight, two men on drop tests (one day and one night), two men make surface inspection.

Delaware, Lackawanna & Western

Inspector in charge, two assistants and two chemists. The inspection starts at the soaking pits and continues through all operations to the loading and shipping.

Grand Trunk.

Inspection done by Robt. W. Hunt & Co.

Hunt & Co.

A chief inspector at each mill and staff varying according to the output of the mill, sufficient to inspect manufacturing operations from the making of the steel to the loading of the rails. Steel inspectors in open-hearth or bessemer plants, blooming mill inspectors, rail mill inspectors, drop test inspectors, final inspectors and a clerk.

New York Central.

Force of seven inspectors. Specific duties not assigned to each man but he covers entire process of manufacture, drop testing and final inspection.

New York, New Haven & Hartford.

For two shift rolling, staff consists of chief inspector, a day and night inspector of tests and two surface inspectors. For single shift rolling, this may be reduced to chief inspector, one inspector of tests and one (or two) surface inspectors.

Norfolk & Western.

Organization consists of men familiar with mill practice and capable of making all tests. Duties consist of making specified tests and recording results, checking section, drilling and straightening and surface inspection.

Pennsylvania.

Force consists of 21 inspectors and 1 clerk who inspect all the various kinds of material ordered for maintenance of way, signal and bridge work.

Philadelphia & Reading.

Chief Inspector, three or four assistant inspectors, one chemist and one or two checkers. Chief Inspector follows mill practice and makes drop tests on day turn. One assistant makes drop tests at night and follows mill practice. Other assistant inspectors walk rails making surface inspection. The chemist makes analyses of drillings from finished rail. The checkers record number of rails of each heat loaded into each car.

Southern.

Staff of four to six inspectors. Chief Inspector in charge and makes drop tests. One man assigned to night duty making tests and other work. Two to four men on surface inspection, loading, etc.

3. Selection of Samples for Analyses.
4. Arrangement for Making Analyses.

Baltimore & Ohio.

Mill provides copy of ladle analysis for each heat. Drop test inspector witnesses drilling of test rail from each heat for check analyses. The drilling from each heat, taken transversely through the head of the rail are sent to Baltimore each day to have check analyses run.

Canadian Pacific.

Inspector observes pouring of test ingot. Mill laboratory takes drillings and makes analyses. Own chemist makes occasional check analyses of samples sent him. No analysis of finished rail.

Chicago, Rock Island & Pacific.

Test ingot from which mill secures drillings is cut in two and also one-half of drillings which mill takes are submitted. These are sent to Chicago and analyses made in railroad company's laboratory.

Delaware, Lackawanna & Western.

Ladle test sample is accepted as delivered by the mill to the laboratory. The specimen cut for rail analysis is identified. It is cut from immediately behind the drop test piece, taken from the first ingot of the heat. The Railroad's chemist makes analyses for carbon, phosphorus and manganese in the laboratory of the steel company who furnishes all equipment and chemicals for the purpose.

Grand Trunk.

Same practice as Canadian Pacific.

Hunt & Co.

At least three times each week inspectors follow the ladle test ingot of a heat to the mills chemical laboratory and obtain a portion of the drillings taken from the mill's work, the purpose being to obtain identity of mill and inspector's samples. The drillings are forwarded to the Chicago laboratory, for analysis. The laboratory follows, in so far as is practicable, the methods prescribed by the A. S. T. M.

New York Central.

Drillings are taken from ladle test ingots and analyses are made by mill chemists. Occasional check analyses are made in New York Central laboratories.

New York, New Haven & Hartford.

Ladle test samples taken by mill and analyses made by mill chemists. For check analyses a short section is cut from a rail bar of each heat, and drillings are also frequently taken from the broken drop test pieces. All analyses are made in the regular mill laboratory without supervision by railroad inspectors.

Norfolk & Western.

Analyses of ladle test ingots furnished by the mill. In addition drillings are obtained from ladle test ingots of each heat and forwarded to Roanoke where occasional check analyses are made.

Pennsylvania.

Analyses of ladle test ingots furnished by the mill. Occasional check analyses on ladle test ingot or rail made at Atloona on samples selected by inspector.

Philadelphia & Reading.

Analyses made of finished rail. Drop test piece stamped by inspector and drillings taken from corner of head in his presence. At two mills railroad chemist makes analyses in mill laboratory. At the other mill the procedure is the same except that the mill chemist makes the analysis and check analyses are made at Reading by the Railroad.

Southern.

Mill furnishes analyses of ladle test ingot and also furnishes part of drillings. Also inspector personally selects drillings from a finished rail from every tenth or twelfth heat. All check analyses made by railroad at its own laboratory.

5. Samples for Drop and Other Physical Tests.

Baltimore & Ohio.

Drop test sample selected from first rail rolled from second, middle and last full ingot.

Canadian Pacific.

In addition to the usual three drop tests from a heat, a nick and break test is made of each ingot, of a piece twelve inches long. If the fracture shows pipe or segregation or other interior defects, the upper rail of that ingot is rejected and a fracture test made of the next lower rail.

Chicago, Rock Island & Pacific.

Drop tests from second, middle and last full ingot. Tested alternately with head and with base in tension. One specimen of each heat tested to destruction and taken in rotation from the second, middle and last full ingot of the heat. In case any test piece shows a piped condition, it is re-nicked and broken, and if the fracture shows clear, the rails represented by it are accepted as to fracture.

Delaware, Lackawanna & Western.

In most cases select drop test pieces from first, middle and last full ingot. This is optional.

Grand Trunk.

Drop tests and nick and break tests same as described for Canadian Pacific.

Hunt & Co.

The proper ingots are followed through and the drop test pieces (or other) assured of being cut as prescribed. Pieces for retest are cut only after complete identification.

New York Central.

Test butt taken from the top crop of the second, middle and last full ingot. The exhausted ductility developed in one of the three test butts taken in rotation.

New York, New Haven & Hartford.

Drop test pieces cut out at hot saws from top of rail bar of second, middle and last ingot. Re-tests are usually from rear end of rejected rails as representing top ends of rails of next letter.

Norfolk & Western.

Test specimens selected from second, middle and last full ingot.

Pennsylvania.

Drop test pieces all cut from front end of rail representing top of the ingot.

Philadelphia & Reading.

Drop test pieces cut from the top of the A rail of the second, middle and last full ingot of each heat. Six inch specimens are also cut from drop test piece from each heat and sent to the railroad laboratory from which tensile test pieces are cut; one from the corner of the head and one from the center of the head. Check analyses are also made on drillings taken from these six inch test pieces.

Southern.

Drop test samples are selected from the front end of top or A rails.

6. Determination of Deflection.

Baltimore & Ohio.

Three foot straight edge. The scale is laid off in tenths of an inch, and is set in the center and at right angles to the straight edge.

Canadian Pacific.

Test specimen placed in the drop machine head up. Deflection is measured by a straight edge having two standards three feet apart, and a scale in the center that works freely through a slot in the straight edge perpendicularly, graduated the deflection measured from the center of the test piece to the bottom of the straight edge.

Chicago, Rock Island & Pacific.

The permanent set is measured in a length of three feet, the deflection being measured at the center of a graduated scale.

Delaware, Lackawanna & Western.

Instruments used consist of a steel straight edge and a steel gage graduated into hundredths of an inch.

Grand Trunk.

The test specimen placed in the drop machine head up, instrument for measuring deflection the same as described for Canadian Pacific.

Hunt & Co.

The deflection is measured by specially designed deflection gage which gives a position reading of the actual deflection in three feet. It is laid on the part of the rail, either head or base, that has not been in contact with the tup, and thus the effect of the frequent indentation made by the tup is eliminated.

New York Central.

Rails 80 to 105 lb. per yard tested with supports three feet apart, and 120 lb. rails with 4 foot supports. Deflection measured by a 3 ft. bar which has a vertical movable scale in the center, reading to hundredths of an inch.

New York, New Haven & Hartford.

The deflection is measured with a 3 ft. straight edge with a vertical sliding scale graduated to tenths of an inch at its center.

Norfolk & Western.

Deflections are measured by means of a straight edge 36 inches in length with vertical graduated scale at center.

Pennsylvania.

A 3 ft. straight edge with vertical sliding scale in middle is used to measure deflections.

Philadelphia & Reading.

Deflection is determined at the center of the test piece after each blow of the drop hammer. The usual straight edge with rule running through it at right angles is used for measuring the deflection.

Southern.

Rail deflections are taken by means of a straight edge and steel scale. The rail test sample is drop tested head up and the deflection is taken from the top of the head.

7. Determination of Elongation.

Baltimore & Ohio.

Prick punch marks one inch apart on either head or base for three inches on each side of the center of the rail. Elongation measured with a scale laid off in hundredths of an inch.

Canadian Pacific.

Do not use elongation tests.

Chicago, Rock Island & Pacific.

Test piece laid off with prick punch marks as per specification and elongation measured with a scale graduated to hundredths of an inch.

Delaware, Lackawanna & Western.

Elongation measured with a flexible steel scale graduated in hundredths of an inch.

Grand Trunk.

Do not use elongation tests.

Hunt & Co.

The 1-inch spaces required are punched, generally by gang punches, and the elongation of each measured by a small spring scale laid on the rail surface close to the punch marks.

New York Central.

A spacing bar of seven hardened steel points, one inch apart, is applied to the base or head, and then struck with a copper hammer. The stamped portion of the rail is placed midway between supports. The elongation of each inch is measured by a scale reading to hundredths of an inch.

New York, New Haven & Hartford.

The drop test pieces are marked in the center of their length into six one-inch spaces. The marking is done with a seven-point punch on head or base. After each blow the elongation is measured with a flexible steel scale graduated to 1/50ths of an inch. The total elongation in six inches should be read independently as a check on the readings of each inch.

Norfolk & Western.

Elongation in each inch for a length of 6 inches is measured with a flexible steel scale graduated to 100ths of an inch.

Pennsylvania.

Use a scale six inches long reading to 100th of an inch.

Philadelphia & Reading.

Seven marks are made upon the head or base of the rail, three marks on either side of the center of the test piece. The elongation between each two marks is measured by means of a steel rule reading to 100ths of an inch.

Southern.

Rail test samples are prick punched 1 inch apart on the base and the elongation is taken with a steel scale graduated in 100ths of an inch.

8. Surface Inspection of Rails.

Baltimore & Ohio.

The heat number, the letter and the branding are first checked. The inspectors walk each rail on top, bottom, and each side for defects, the mill men turning the rail for each operation. At the same time the ends of the rail are checked for drilling and inspected for pipes or crooks.

Canadian Pacific.

The four sides of the rail are walked to detect any flows or mechanical defects. The drilling is checked. Second quality rails are checked to see that they are properly painted and prick punched and to see that they are loaded separately on cars.

Chicago, Rock Island & Pacific.

Rails first walked with bases up and then walked with heads up. Then inspected for crooks, drilling checked and examined for piping in the bolt hole or end of the rail. Next checked for length with a steel tape. Rails which have been marked for crooks are sent to the re-straightening press and those with defects that can be cut back are sent to the cold saw.

Delaware, Lackawanna & Western.

Rails are first laid on their side with heat number and letter up and rejected rails removed. Rails are then inspected for surface and line. Those out of line are sent back for restraightening. Any rails in which flaws are found are either rejected or made second quality according to the degree and nature of the flaw. The drilling in the most part is taken care of in the finishing mill. The lengths of rails are checked in the finishing mill. Any 33-ft. cold saw rail found is laid aside until the end of the rolling and annealed with an acetylene torch to remove the brittle steel at the end of the rail.

Grand Trunk.

Same as described under Canadian Pacific.

Hunt & Co.

The finished rails are laid out in tiers on the inspection beds, either head or base up. The final inspectors walk them from end to end, usually directing their specific attention on one trip to three or four rails. Any flaws or imperfections seen are examined and the rails marked accordingly with pre-arranged classification marks. After this inspection the rails are turned 180° and the process repeated, so that each rail sent out for shipment is inspected on two sides. After the walking of the rails is completed the inspectors examine the ends of the rails for mechanical finish and measure the lengths when considered desirable. The rails are then sighted for straightness and the ends examined for indication of piping.

New York Central.

The rails upon the inspection beds are walked by our inspectors on head, web and base, for flaws and imperfections, and the ends are examined for pipes in the web or head. If any surface defects are found, the rails are marked as second quality or scrap. They are also marked for surface defects in the head, web or base near the ends, to be cut at the saws into short lengths. Drillings, straightness of line and surface, sawing of the ends, stamping and branding, length of rail, fish and finish of the sections are also inspected and checked.

New York, New Haven & Hartford.

Surface inspection by the mill's inspectors is performed before the rails are drilled. After drilling the rails are walked, both head up and base up by the surface inspectors. It is customary at most mills for the inspector to examine the heads of three rails or the bases of four each time he walks the lengths of the pile. After the heads and bases are inspected and the heat numbers examined to guard against the acceptance of rails rejected at the drop test, and to pick out rails of heats over .71 in carbon for painting red at ends, the surface inspector walks along the ends of the spread or lift of rails and examines the ends of the rails for defects and sights them for straightness.

Norfolk & Western.

Surface inspection is given the heads, webs and bases of rails offered for acceptance and delivered on loading skids.

Pennsylvania.

Rails are inspected for surface, finish and straightness before loading, all rails turned that each side, top and bottom may be looked over.

Philadelphia & Reading.

Rails are inspected for straightness, seams, etc., on the loading beds. Inspectors walk four sides of the rails and also inspect the ends, examining them for pipes, etc. The section is checked both in the mill at the hot saws and on the loading beds. No inspector stationed at the straightening presses. The drop test inspector looks after this department, as only a portion of his time is taken up with making drop tests.

Southern.

Surface inspection consists of an examination of the head, base and web of each rail for local defects, an examination of the machined (milled) ends of same for evidence of interior defects (pipes), sighting the rails along both the line and the surface for straightness and checking the drilling, sawing, lengths, etc.

9. Records of Manufacture.

Baltimore & Ohio.

Each heat is followed from the pouring at the open-hearth furnaces to the finishing beds and all information as regards the history of the heat and the disposition of same is recorded in rail book, form 1632-B.

Canadian Pacific.

Records are kept of drop test, nick and break test, chemical analysis, heating and blooming of each heat in a heat record, where provision is made for the failures of each heat to be recorded under the particulars of each heat.

Chicago, Rock Island & Pacific.

None before the rolling of the ingots.

Delaware, Lackawanna & Western.

Following records of manufacture are kept by railroad inspectors: Open-hearth records of ingots made, records of ingots charged into the pits, time ingots are kept in the pits, weight of ingots, amount of discard from top and bottom, length at hot saws.

Grand Trunk.

Same as Canadian Pacific.

Hunt & Co.

Steel, blooming mill, rail mill and drop test inspectors keep records pertaining to manufacture and testing. Special forms are used providing for a complete record of the making and rolling of each heat.

New York Central.

Records are kept of the details of manufacture and include mill records, notes by inspectors, and the record of tests and inspection.

New York, New Haven & Hartford.

Record kept of general method of manufacture, size of ingots, number of ingots, discard, shrinkage allowance at hot saws, blooms reheated or not.

Norfolk & Western.

Reports of inspection show for each rolling the number of ingots cast and rails rolled from each heat, the size and weight of ingots, the number of passes in rolls from ingot to finished rail, the discard from top and bottom of ingot, shrinkage, check weights, the total of first and second quality rails accepted, number of rails rejected, with cause for rejection, and this information is from time to time supplemented by a special report covering the complete process of manufacture including raw material, fuel, mill design and output.

Pennsylvania.

Records are kept of all heats rolled, number of ingots to heat, number of rails to ingot, size of ingot and average percentage of discard from top and bottom.

Philadelphia & Reading.

No permanent records are kept of the mill practice. Any changes are noted in inspector's report which is kept in book form.

Southern.

Record kept of any details of manufacture worthy of special interest.

10. Checking Against Errors.

Baltimore & Ohio.

Heats and rail letters are checked on loading beds to see that only accepted rails which have passed tests and inspection, are loaded.

Canadian Pacific.

The open-hearth inspector keeps track of special ingots such as "stickers" and others. Rejected rails are separated. Care is taken to check up the number of ingots and number of rails from each heat.

Chicago, Rock Island & Pacific.

Before loading commences, all rejected rail must be shown to the Chief Rail Inspector, and in addition to this he checks the rails as they are loaded.

Delaware, Lackawanna & Western.

The loading inspector is supplied with accepted heat numbers, and number of rails in each heat. Rejected rails found are separated and scrapped.

Grand Trunk.

Same practice as with Canadian Pacific.

Hunt & Co.

The work of inspection being of a progressive character insures against rolling odd ingots and blooms to a very large extent. There is always a slight possibility that heat number stamping and rail lettering will be incorrect but that too is practically eliminated by this plan of inspection. Rails are loaded almost as rapidly as inspected and rejected rails are marked plainly and set aside.

New York Central.

Inspectors oversee the loading of the cars which is done adjacent to the inspecting beds.

New York, New Haven & Hartford.

Rejected rails are immediately culled from accepted ones and piled separately. Surface inspectors also check the heat numbers.

Norfolk & Western.

Heat numbers are examined on the loading skids. Where cold ingots are charged from stock, the heat numbers are examined and odd heats tested.

Pennsylvania.

Checks are made at different times during rolling of method of handling each heat through the various stages, but depend mostly on mill people to keep heats together and their efforts are not faulty.

Philadelphia & Reading.

In order the prevent rejected rails, or rails rolled from odd ingots, being shipped, and also to keep a record of where rails of each heat are shipped, a record of the number of rails of each heat, loaded into each car, is kept.

Southern.

Inspectors are required to witness the loading of the rails and make record of the cars in which loaded. Inspectors are also required to check the heat numbers of the rails while being loaded, which records are checked against the heats tested.

11. Other Comments and Suggestions.

Baltimore & Ohio.

Cooling beds should be covered. Drilling of rails should be carefully checked. Rejected rails should be marked near the center so they cannot be again offered as short rails. The manner of marking and branding should be clearly defined in the specifications. Special and second quality rails should be loaded in separate cars.

Delaware, Lackawanna & Western.

Rails at the hard side of the specifications are painted red, and those at the soft side are painted blue.

New York Central.

Record should be kept of details of manufacture.

Southern.

The front ends of all rails are milled in order to better detect the presence of pipes.

Appendix C

FORMULA FOR ELONGATION OF RAILS IN THE DROP TEST

By M. H. Wickhorst

The drop test of rails is primarily a means of testing their ductility and, when first used, the height of drop that the rails would stand without breaking was naturally used as the measure of ductility. In 1891 Dr. P. H. Dudley developed a means of determining directly the ductility by measuring the stretch between a series of prick punch marks placed on the part of the rail placed in tension. This method has come into general use but the simple height of drop is thought by some to be perferable as the operation of testing can be carried out more quickly and the height of drop can be adjusted more accurately than the per cent. of stretch in one inch can be measured. This paper is a discussion of the relation between the height of drop and the elongation of the outermost fibers in tension, and presents also a formula by which the height of drop necessary to produce a given elongation, or the elongation that will be produced by a given height of drop, can be calculated.

The factors of which the elongation is a function, and which need consideration in the present discussion, are the height and weight of drop, the weight and section of the rail and the composition of the steel, mainly the carbon content.

The elongation within the elastic limit would increase directly as the foot-pounds of load applied, which for a tup of 2,000 pounds would be a height of drop of less than one foot. Beyond the elastic limit and for heights of drop usual for the first blow, the elongation would be expected also to vary about as the height of drop and this has been confirmed by experimental determinations. (See Report 1, Proceedings American Railway Engineering Association for 1911, Vol. 12, Part 2, page 392.)

Within the elastic limit, the elongation would vary inversely as the first power of the section modulus and within ranges of height of drop usual for the first blow, would be expected to follow about the same law. The writer is not aware, however, that it has been determined from experimental data, how closely this law is followed.

The deflection of the rail on the first blow (which is a measure of the stiffness) decreases as the carbon increases and likewise the elongation of the fibers in tension decreases with increase of carbon. The quantitative effect of carbon on the elongation on the first blow of the drop was worked out for 80 lb. A.R.A. type A rails and the results of the research were presented in a diagram in Report 40 on the "Influence of Carbon on the Properties of Rails." (See Proceedings American Railway Engineering Association for 1915, Vol. 16, p. 165.) Taking the curves of elongation on the first blow for head tension and base tension as a basis of calculation, it figures out that each .01 per cent. change in carbon causes a change of approximately one per cent. in the elongation on the first blow, when the elongation with carbon at .70 per cent. is taken as a basis of comparison.

If the elongation at .70 per cent. carbon is taken at 100, and the carbon is expressed in .01 per cent., then the elongation varies inversely as the carbon plus 30. This is to say, the elongation varies inversely as the per cent. of carbon plus .30.

From the above considerations a formula may be constructed for calculating the elongation on the first blow for different conditions of rail section, height of drop and carbon content. The following symbols may be used.

E = elongation in per cent. in the maximum inch on the first blow. Supports 3 ft. apart.
h = height of drop of a 2,000-lb. tup, in feet.
C = carbon in per cent.
X = section modulus of the rail section.
K = a constant.

The formula would take the following form:

$$E = \frac{K\,h}{X\,(C + .30)}$$

The value of K must, of course, be determined from the results of elongation measurements and through the kindness of the Illinois Steel Company, elongation figures obtained at Gary in the course of inspection work, were used for the purpose. A variety of rail sections were represented and the results from about twenty heats for each section were used. Three tests had been made of each heat and the average longation of the three maximum inches were used as the elongation of that heat on the first blow. For each section, the section modulus and height of drop remained the same, but there were variations of carbon and elongation on the first blow. K was solved for each heat and then the arithmetical average for each section determined, separate averages being determined for the head tension and base tension tests. The results of the determinations of K are given in Table 1, which are figured from the Gary inspection work, except those for the 80 lb. A.R.A. type A rail, which were taken from Report 40 mentioned above. Of course for precise work, the elongation measurements should be much more refined than is the practice in inspection work, but these figures will answer as a first approximation.

TABLE 1—VALUES OF K

Pounds per Yard	Section	Sec. Modulus		Value of K	
		Head	Base	Head Tens	Base Tens
80	RA-A.........	10.24	12.46	5.05	5.05
80	ASCE.........	.....	11.97	....	5.07
85	RA-A.........	10.96	13.06	4.78	4.37
85	ASCE.........	.....	12.00	....	4.30
90	RA-A.........	.....	15.23	....	4.91
90	RA-B.........	11.45	13.21	4.99	4.13
90	GN...........	.....	12.30	....	3.98
100	RA-A.........	.....	17.78	....	5.55
100	RA-B.........	13.70	15.74	5.15	4.56
100	ASCE.........	.....	16.11	....	4.84
100	C&NW........	13.29	16.97	4.89	4.94
105	Dudley........	.....	17.53	....	4.73
130	Penna.........	20.60	23.50	4.74	5.33
General Average...4.81					

Taking K as 4.8 the formula then becomes

$$E = \frac{4.8\,h}{X\,(C + .30)}$$

It is usual in specifications to require a minimum elongation of six per cent. and the heights of drop which would be required to just give this amount of elongation in the maximum inch on the first blow, as calculated by the formula, are shown in the Table 2 for the RE, the ARA and the ASCE sections.

TABLE 2—HEIGHTS OF DROP FOR SIX PER CENT. ELONGATION

Section	Modulus		Carbon	Height of Drop—Feet	
	Head	Base		Head Tens	Base Tens
80-ARA-A.....	10.24	12.46	.60	11.5	14.1
80-ARA-B.....	9.38	11.08	.60	10.6	12.5
80-ASCE......	10.30	11.97	.60	11.6	13.4
85-ASCE......	11.16	12.00	.70	13.8	15.0
90-ARA-A.....	12.56	15.23	.70	15.6	19.0
90-ARA-B.....	11.45	13.21	.70	14.4	16.5
90-ASCE......	10.59	12.18	.70	13.2	15.2
100-RE.........	15.10	17.80	.70	18.8	22.2
100-ARA-A.....	15.04	17.78	.70	18.7	22.2
100-ARA-B.....	13.70	15.74	.70	17.2	19.7
100-ASCE......	14.44	16.11	.70	18.2	20.0
110-RE.........	16.70	20.10	.70	21.0	25.0
120-RE.........	18.90	23.10	.75	24.9	30.5
130-RE.........	20.80	25.60	.75	27.5	33.5
140-RE.........	23.10	28.40	.75	30.5	35.4

These heights have been figured for the average specified carbon and it will be interesting in this connection to consider the quantative influence of variations in the amount of carbon on the height of drop required to produce six per cent. elongation. It figures out for the 100 lb. rails that to reduce the carbon to the lower limit of the specifications would reduce the height of drop about 1½ ft. and to increase the carbon to the upper limit would raise the height of drop about 1½ ft. to produce the same elongation. In other words there is a range of about 3 ft. in the heights required to produce six per cent. elongation, between the lowest and highest carbons specified.

Rail specifications usually fix the height of drop to be used in testing rails and the normal elongations of the maximum inch produced by the first blow from the heights specified in the 1920 AREA specifications are shown in Table 3 for RE, ARA and ASCE sections. It will be noted that for the purpose intended, the height is adjusted about right for the 90 lb. rails, but is high for the lighter weight rails and low for the heavier rails.

Table 3—Elongations on First Blow

Section	Carbon	Height, Feet	Elongation, Percent	
			Head Tens	Base Tens
80-ARA-A	60	17	8.8	7.3
80-ARA-B	60	17	9.3	9.0
80-ASCE	60	17	8.8	7.6
85-ASCE	70	17	7.4	6.8
90-ARA-A	70	17	6.5	5.4
90-ARA-B	70	17	7.2	6.2
90-ASCE	70	17	7.7	6.6
100-RE	70	18	5.7	4.8
100-ARA-A	70	18	5.7	4.8
100-ARA-B	70	18	6.3	5.5
100-ASCE	70	18	6.0	5.3
110-RE	70	18	4.4	5.0
120-RE	75	20	4.8	3.9
130-RE	75	20	4.4	3.6
140-RE	75	20	4.0	3.3

Finally it may be remarked that the primary quality determined by the drop test is the longitudinal ductility of the part in tension and when the height of drop is used as the measure of ductility it should be adjusted for each section as well as weight of rail, and perhaps also for the carbon content of the steel in the rail being tested.

Appendix D

BIBLIOGRAPHY AND DISCUSSION OF INTERIOR FISSURES IN RAILS

By M. H. Wickhorst

A bibliography of the subject of interior fissures in rails was prepared covering the literature of the years 1911 to 1915 inclusive and was contained in Report 52 on the subject of "Internal Fissures in Rails." (See Proceedings American Railway Engineering Association, Vol. 17, 1916, pages 587-590.) The discussion on fissures has been revised and the bibliography has been extended five years, to include the year 1920.

Types of Interior Fissures

Interior fissures may be divided into three types as follows:

(1) Simple transverse fissure.
(2) Simple horizontal fissure.
(3) Compound fissure.

An illustration of the simple transverse fissure is given in Fig. 1.

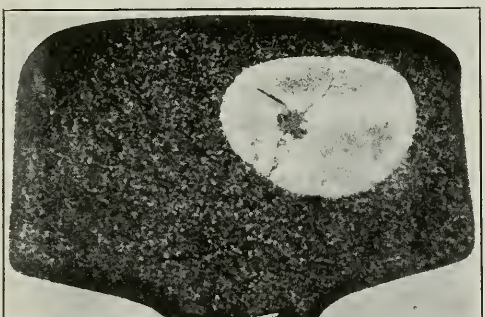


Fig. 1. Sample of Transverse Fissure.

This type of failure first came prominently to public attention in J. E. Howard's report on the Manchester wreck on the Lehigh Valley Railroad, that occurred August 25, 1911. The transverse fissure is an oval spot in the interior of the head varying in size from ¼ inch or less in diameter to almost the full section of the head. A characteristic and constant feature of this type of fissure is the "nucleus," a granular or crystalline spot surrounded by the smooth or polished part of the fissure. The nucleus is ordinarily about ¼ inch in diameter but may be smaller or much larger. The surrounding smooth part has been found in all sizes from nothing to almost the full size of the head. Our present information indicates that the nucleus is a shrinkage check in the interior of the head, which acts as a center of growth, from which the fissure develops under repeated "alternations of stress" or the "wave action" under moving trains.

The horizontal fissure is one that lies imbedded in the rail in a horizontal position parallel with the top of the head and generally from one-

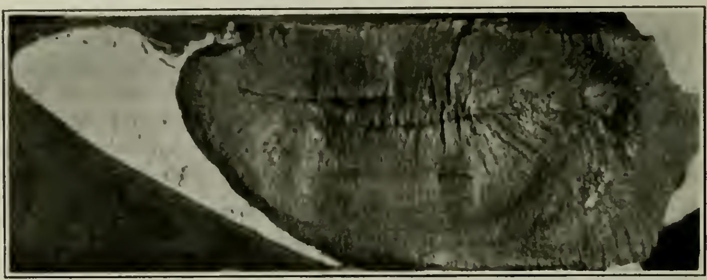


Fig. 2. Sample of Horizontal Fissure, Looking Down on Top of Head.

half to three-fourth inch below it. An illustration of it is given in Fig. 2. The simple horizontal fissure is not, however, frequent in rail that have broken in the track, because before the point of breakage is reached, a transverse crack branches off from the horizontal one, finally breaking as a compound fissure, as illustrated in Fig. 3. These two kinds of fis-

Fig. 3. Sample of Compound Internal Fissure.

sure are really only one type and start from longitudinal streaks (mostly non-metallic inclusions) in the interior of the head. The fissure first grows laterally and longitudinally from the streak and after awhile a branch develops up or down from the horizontal crack, or perhaps up at one end and down at the other, finally resulting in a fracture of the rail. These fissures occur mostly in the upper rail of the ingot and are closely allied to the type of failure known as "split head." This latter is perhaps a fissure, but it is a type of failure that has been long known as "piped" rail and it is well to keep it in a separate classification.

The Cause of Transverse Fissures

Our present information indicates fairly definitely that simple transverse fissures develop from shrinkage checks in the interior of the rail head, or from a shattered condition inside. The evidence that transverse fissures have their origin in shattered steel in the interior has been a matter of gradual growth. In the early investigations it had been noted that simple transverse fissures always developed from a granular nucleus; also, that although the metal was generally satisfactory from a chemical standpoint, it was of low ductility in the interior of the head, without, however, the reason being clear for the low ductility while the other parts of the rail section showed good physical properties.

The papers by Wickhorst in 1915 "Study of a Rail with Internal Fissures," and "Internal Fissures in New Rails," and also later papers, called attention to the presence of cracks in the interior of the rail head. The method of examination was to etch sections with copper chloride solution and the polish the etched section, but this method was comparatively cumbersome and only partly effective. It remained for the admirable work of F. M. Waring and K. E. Hoffammann at the Altoona Laboratory, published in 1919, to use the method of deep etching, which so simply and effectively discloses the shattered condition. There was still some question as to whether the cracks disclosed were not produced in the etching, but the work of Rawdon at the Bureau of Standards showed that the cracks are pre-existent; that is, they exist previous to the etching. Rawdon also showed that the walls of the cracks are apt to be in such intimate contact that the cracks may not be observed even with the usual microscopic examination, but need strong etching or other special examination to make them visible.

More recent work has shown that the shattered condition is confined to the interior of the rail and does not extend fully to the end of the rail as hot-sawed at the mill, but terminates about one-half inch short of the end. This indicates that the shattering was not in the hot rail bar as rolled but is a condition of shrinkage checking developed in the cooling. Further work on the subject should not be directed toward determining the conditions under which the shattering occurs and also the conditions necessary to prevent its occurrence.

The Cause of Horizontal and Compound Fissures

As already mentioned above, the cause of the longitudinal fissures, usually with transverse branches, otherwise called compound or coalescent fissures, is of a different nature from the cause of the simple transverse fissures. The longitudinal fissure spreads out from a longitudinal streak which seems generally to be a thread of non-metallic inclusion in the interior of the head. Tablations, notably those by Dr. Dudley, have shown that this type of failure occurs mostly in the upper rail of the ingot. It is closely related to the split head and probably the remedy is the some for both; namely, a clean, well deoxidized steel with a liberal top discard or with a sink-head ingot.

Bibliography

The literature on the subject of fissures in rails starts with J. E. Howard's report on the Manchester wreck on the Lehigh Valley in 1911, when, as above stated, the transverse fissure first came prominently to public attention. While not exhaustive, it is believed that the bibliography and abstracts given below are a fairly full representation of the literature on the subject. The bibliography from 1911 to 1915, inclusive, is taken from the former report and is extended to include the year 1920, which extension was largely prepared by John B. Emerson. It includes also some references to the literature of "snow-flakes" found in gun and other forgings, which seems to be a closely related subject.

INTERNAL FISSURES IN RAILS

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1912.

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"Types of Defective Rails and Some Methods Used in Detecting Them." By Robert Job. Railway Age Gazette, Vol. 53, p. 954, November 15, 1912. Paper presented at Sixth Congress of the International Association for Testing Materials, New York, September, 1912. Among other types of rail failures Mr. Job presented illustrations of transverse and compound internal fissures. Concerning them he remarked that "thorough study proved beyond question that the composition of the steel in its ordinary elements was not the cause of the failure, and also that the conditions of service were not the prime cause."

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1913.

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1914.

"Interstate Commerce Commission Investigation of Southern Railwas Accident near Oyama, N. C." Report by Chief Inspector of Safety Appliances, dated January 7, 1914, of accident on March 31, 1913, embodying report by J. E. Howard. The same explanation of the formation of fissures is given as in the previous cases.

"Internal Transverse Cracks and Fissures in Rails." By Robert Job. Railway Age Gazette, Vol. 56, p. 266, February 6, 1914. Illustrations are given of rails showing transverse fissures, including some that occurred in Austrian rails, copied from a publication by Dormus at Vienna in 1901.

Mr. Job concludes that "traffic conditions were not the prime cause of the growth of the cracks," but that the cause of the failure is to be looked for in the condition of the steel.

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"A Study of Interior Transverse Fissures in Rails." By P. H. Dudley, Railway Age Gazette, Vol. 56, p. 415, February 27, 1914. Editorial comment on p. 411. Illustrated article in which the fissure is attributed to various conditions of manufacture, and particularly to the bad effect of the gagging when straightening the rail.

"Internal Transverse Defects in Steel Rails." By Robert Job. Iron Age, Vol. 93, p. 660, March 12, 1914. From the article in the Railway Age Gazette, February 6, 1914.

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"Fatigue of Rails." By Paul Kreuzpointner, Railway Age Gazette, Vol. 57, p. 755, October 23, 1914. A discussion of "fatigue," or detail fracture with illustrations of the difference in the appearance of such fracture in good or sound material and in defective material.

"Interstate Commerce Commission Investigation of Delaware, Lackawanna & Western Accident near Alford, Pa." Report by Chief Inspector of Safety Appliances, dated December 31, 1914, of accident on October 31, 1914, embodying report by J. E. Howard. The conclusion is expressed "That the growth of transverse fissures is the result of repeated stresses, and their formation occurs in consequence of overloads applied to the rails in service."

1915.

"Study of a Rail With Internal Fissures." By M. H. Wickhorst. Proceedings, American Railway Engineering Association, Vol. 16 (1915), p. 195. Results of an examination of a rail that had failed in service due to transverse fissures. It showed numerous small cracks, mostly longitudinal, in the interior of the head.

"Internal Fissures in New Rails." By M. H. Wickhorst. Proceedings, American Railway Engineering Association, Vol. 16 (1915), p. 389. Illustrations are given of some small longitudinal cracks found in new rails.

"Interior Transverse Fissures." By P. H. Dudley. Proceedings, American Railway Engineering Association, Vol. 16 (1915), p. 1120. Illustrated discussion by Dr. Dudley, presenting part of a letter to the President of the New York Central Lines. Attention is called to the harmful effect of the gag press in the cold straightening of rails.

"The Failure of Material Under Repeated Stresses." By H. F. Moore and F. B. Seeley. American Society for Testing Materials, Vol. 15, 1915, p. 437. While not dealing specially with rails, this paper gives a full discussion of the subject of "fatigue" of metals, or fracture in detail under repeated stresses, together with a bibliography of the subject.

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"Gagging Rails and Transverse Fissures." By A. W. Thompson. Railway Age Gazette, Vol. 59, p. 888, November 12, 1915. Expresses the thought that the elimination of gagging would probably not overcome the transverse fissure.

"Transverse Fissures the Result of Rail Gagging." By P. H. Dudley. Railway Age Gazette, Vol. 59, p. 1001, November 26, 1915. Exhibits two types of interior transverse fissure, the intergranular and coalescent types. The intergranular (or simple transverse) fissure is explained as due to gagging on the base in straightening and the coalescent (or compound) fissure is explained as due to gagging on the head.

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1916.

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Development of Rail Manufacture. By Dr. J. C. Unger. Railway Review, July 15, 1916, Vol. 59, p. 72. Expresses opinion that Transverse Fissures are always due to cold rolling in track and excessive vibration, and can be eliminated by providing rail supports secure enough to prevent the vibration.

Same article. Railway Age Gazette, June 2, 1916, Vol. 60, p. 1174.

Discussion by W. C. Cushing, Railway Age Gazette, June 16, 1916, Vol. 60, p. 1319. Calls attention to development of fissures on bridge track where ties are nearly contiguous, referring to records of failures in print in Proceedings of American Railway Engineering Association, Vol. 14 (1913), pp. 414 and 421.

Internal Fissures in Rails. By Rail Sub-Committee, W. C. Cushing, Chairman, Proceeding of the American Railway Engineering Association, Vol. 17 (1916), p. 585. Fissures are divided into three types, the simple transverse, the horizontal and the compound fissure, showing both horizontal and transverse types. A bibliography is given covering the years 1911 to 1915 inclusive. Some results are given indicating that "transverse fissures occur indiscriminately in the several rails of the ingot and that segregation is not an important factor in causing the fissure."

This article is abstracted in Engineering Record, April 8, 1916, Vol. 73, p. 475, and also in Iron Trade Review, March 30, 1916, Vol. 58, p. 706.

1917.

Induced Interior Transverse Fissures in Heads of Two Types. By Dr. P. H. Dudley. Proceedings of the American Railway Engineering Association, Vol. 18 (1917), p. 1055. Interior Transverse Fissures are classified as "intergranular" and "coalescent." They are ascribed as due to a physically non-ductile core of heterogeneous metal near the center of the head resulting from delayed transformations. Intergranular fissures result from the gagging of a rail coming "low" from the hotbed and the coalescent type result from the gagging on the head of a high rail.

This paper is abstracted and discussed from preprints as follows:

Iron Age, December 28, 1916, Vol. 98, p. 1451.

Engineering Record, August 26, 1916, Vol. 74, p. 269.

Iron Trade Review, August 17 and October 12, 1916, Vol. 59, pp. 331 and 729.

Railway Age Gazette, January 12, 1917, Vol. 62, p. 55.

Some Transverse Fissure Rails on the Louisville and Nashville Railroad. By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 18 (1917), p. 1189. The result of an examination of eleven rails that had failed in service due to interior fissures. Chemically the rails showed a tendency to hardness but were in general free from segregation. Physically the rails showed good properties except in the interior of the head where the metal contained numerous small cracks and was of low ductility.

The Fail Failure Situation. By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 18 (1917), p. 1207. Embodied in a discussion of rail failures in general is a discussion of internal fissures. They are classified as simple transverse, simple horizontal and compound. Chemically the rails have been normal with a tendency toward hardness. "Physically the rails have generally shown good physical properties in the different parts of the rail section except in the interior of the head where the ductility has usually been low and frequently entirely absent." "Fissured rails have also shown numerous small cracks in the interior of the head; that is, the metal in the interior of the head was in a generally torn condition."

Interstate Commerce Commission Investigation of Galveston, Houston and San Antonio Accident near Iser, Texas. Report by Chief Inspector of Safety Appliances dated February 12, 1917, of accident on January 31, 1916, embodying report by James E. Howard. Mr. Howard believes the service stresses sufficient to account for the development of fissures in normal rail and that mill conditions are not concerned with them.

Report is abstracted in Railway Age Gazette, March 23, 1917, Vol. 62, p. 623, and in Engineering News, May 31, 1917, Vol. 78, p. 455.

Discussion of report by John D. Isaacs, Railway Age Gazette, May 25, 1917, Vol. 62, p. 1086. Mr. Isaacs takes strong issue with Mr. Howard's conclusions, and directs attention to the excellent behavior of the rail from certain mills as compared with the product of others under similar service conditions, and also the extremely large number of rails in service for many years without failure whose service stresses have been greater than the comparatively small number that have failed.

Transverse Fissures. By E. F. Given. Railway Age Gazette, August 3, 1917, Vol. 63, p. 177. Mr. Given suggests that intensive studies be made of track and equipment in all cases of failure from fissure.

Transverse Fissures. By Geo. W. Dress. Iron Age, April 19, 1917, Vol. 99, p. 943. Mr. Dress suggests that excessive contact of roll cooling water on the rails may contribute weakness leading to fissure. He also calls attention to danger in charging cold ingots into heating furnaces whose temperature is too high.

Discussion by C. W. Gennett in Iron Age, June 7, 1917, Vol. 99, p. 1390. The possibility of these conditions being contributory to the trouble is questioned. Mr. Gennett suggests that attention be turned to the propriety of making mold additions of aluminum.

1918.

Inhibited or Delayed Transformations in Rail Heads. By Dr. P. H. Dudley. Proceedings of American Railway Engineering Association, Vol. 19 (1918), p. 493. Ascribes formation of non-ductile "cores" in the interior of the rail head to delayed transformations on the hot bed. Also suggests greater span of supports for the gag presses.

Transverse Fissures in Steel Rails. By James E. Howard. Transactions American Institute of Mining and Metallurgical Engineers, Vol. 58, (1918), p. 597. Develops Mr. Howard's previous conclusions that service stresses are entirely responsible for transverse fissures. Discussion follows by Messrs. Weymouth and Unger supporting his views, and by Messrs. Hibbard, Gennett, Isaacs, Trimble, Dudley, Ray, Gibbs, Wickhorst and Job presenting their confident feeling that the fundamental cause of fissures lies in abnormal mill practice. Excerpts from this paper are quoted as follows: Iron Trade Review, November 15, 1917, Vol. 61, p. 1055. Railway Age, November 30, 1917, Vol. 63, p. 996. Railway Review, November 24, 1917, Vol. 61, p. 644. Mr. Gennett's discussion is reprinted in Railway Age, February 22, 1918, Vol. 64, p. 421.

Interstate Commerce Commission Investigation of Central of Georgia Accident near Juniper, Ga. Report by the Chief of the Bureau of Safety dated May 2, 1918, of accident on October 30, 1917. Embodies report by Mr. Howard ascribing service conditions as entirely responsible for the development of the fissure causing the accident. This report is abstracted in Railway Review, August 31, 1918, Vol. 63, p. 305.

Interstate Commerce Commission Investigation of Long Island Railway Accident near Central Islip, N. Y. Report by the Chief of the Bureau of Safety dated August 5, 1918, of accident on April 15, 1918. Embodies report by Mr. Howard concluding "the investigations have shown conclusively that neither defective metal nor any physical property or characteristic of the rail structure can be assigned as the cause of the formation of transverse fissures." Reprinted and reviewed in Railway Review December 14-21, 1918, Vol. 63, pp. 843 and 871. It is suggested that spongy structure in the head might retard progress of fissure. Also abstracted in Railway Age, December 6, 1918, Vol. 65, p. 1007, and in the Journal of the American Society of Mechanical Engineers, Vol. 41 (1919), p. 60.

Common Defects in Rail. By C. W. Gennett. Railway Review, October 5, 1918, Vol. 63, p. 498. Discusses Transverse Fissures in connection with other types of failure. Same paper also presented to Roadmasters and Maintenance of Way Convention, 1918.

1919.

Transverse Fissure Fails on Pennsylvania Lines, Heat 31531. By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 465. Result of tests of sixty-one rails, all of one heat, several rails of which had failed in track due to transverse fissures. The carbon was high (.87 per cent.) but there was in general a freedom from chemical segregation. The physical properties were normal except in the middle of the head, where the ductility was low. To detect this conditions the rails should be tested with the head in tension.

Interior Fissure Rails on the Baltimore and Ohio Railroad, Heat 5X157. By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 485. Result of tests of fifty rails all of one heat. The fissures in these rails were of the compound type with transverse fissures branching off from horizontal ones. The metal showed good tensile properties in a longitudinal direction, but transversely was low in ductility. The interior of the head contained streaks of non-metallic material consisting of sulphides, slag and alumina. These rendered the metal in the head somewhat akin to wrought iron, in that it would stretch well lengthwise but was "crumby" when subjected to cross stretching, breaking along a streak.

Transverse Fissure Rails on Delaware, Lackawanna and Western Railroad. Heat 27314. By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 551. A report of the results of test of twenty-five rails all of one heat.

Report on Transverse Fissures. By Dr. P. H. Dudley. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 605. A review and discussion of recent work on transverse fissures is given. Tabulations are presented indicating that fissures are less numerous in rails rolled from reheated blooms than in rails rolled direct from the original heating of the ingot.

Investigation of Transverse Fissures in Failed Rails. By. F. M. Waring. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 614. A report of the result of deep etching with hot hydrochloric and sulphuric acids mixed. This work showed in a remarkable way the condition of shattered steel in the interior of the heads of certain rails, and was the pioneer work in this field with the deep etching method.

Cracks in New Rail. By J. B. Young. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 618. Reports finding cracks in test pieces prepared from new rail.

Rail Investigations During 1918. Review in Engineering News-Record, March 27, 1919, Vol. 82, p. 610, of work of Waring, Young and Dudley.

Interior Transverse Fissures in Bessemer Rail Heads. By. Dr. P. H. Dudley. Proceedings of the American Railway Engineering Association, Vol. 20 (1919), p. 629. Illustrates fissures found in old Bessemer rails and gives some discussion on the subject of interior fissures.

Report of the American Railway Engineering Association Joint Committee on Track. Reviewed in Engineering and Contracting, May 21, 1919, Vol. 51, p. 546. Injury to rails due to flat spots on wheels is discussed in connection with the setting of allowable limits to length.

Deep Etching of Rails and Forgings. By F. M. Waring and K. E. Hofammann. Proceedings American Society for Testing Materials, Vol. 19 (1919), Part 2, p. 183. Continuation of the investigation reported to the American Railway Engineering Association on shattered structure in the heads of certain rails, and concluding "the defects appear to be more frequent in rails that have developed a number of transverse fissures than in others which had only a few or no such fissures. They have also been found to exist in new rails which have not been in track." "We are inclined to believe the cause must be sought in the mill during some stage in the process of fabrication of the material." The paper is discussed by Messrs. J. A. Capps, James E. Howard, W. P. Barba, J. S. Unger, C. B. Bronson, M. H. Wickhorst, H. J. Force, Robert Job, G. Aertsen and G. F. Comstock. Mr. Howard suggests that the cracks may be formed in the cooling of the rails at the mills, and that "The manifestations furnish unquestionable evidence of the presence of numerous cracks, any one of which it would seem might be the starting point of a transverse fissure, among those properly oriented." This is perhaps the first indication on the part of representatives of the Bureau of Safety toward tolerance of an idea that anything other than track conditions might be involved in fissures.

Snowflakes and Fissures. Chemical and Metallurgical Engineering, Vol. 21 (1919), pp. 216-271-342-478-556. A series of articles and reviews by H. M. Howe, Henry S. Rawdon, C. Y. Clayton, F. B. Foley, F. B. Laney, F. Giolitti, H. Styri, and B. E. Field. Snowflakes, the term commonly applied to the internal ruptures in gun and other forgings, are described in great detail and their origin attributed to a great variety of improper mill practices. In Vol. 22 (1919), p. 145, Mr. E. E. Thum reviews the matter and suggests that oxide films may be the joint origin of flakes in forgings and fissures in rails.

Relationship between Transverse Rail Fissures, Flakes and Defects in Fusion Welds. By S. W. Miller. Chemical and Metallurgical Engineering, Vol. 22 (1919), p. 729. Mr. Miller develops the theory that all three are the result of improper metallurgical practice in allowing films of oxide or nitride, probably microscopic, to persist in the product.

Limiting of Transverse Fissures. By Paul Kreuzpointer. Iron Age, August 7, 1919, Vol. 104, p. 360. A plea for better general mill practice, concluding that transverse fissures are the result of combinations of contributory causes, all capable of control by intelligent effort.

A Metallographic Investigation of Transverse Fissure Rails with Special Reference to High Phosphorous Streaks. By G. F. Comstock. Transactions of the American Institute of Mining and Metallurgical Engineers, Vol. 62 (1919), p. 703. An investigation of 24 transverse fissure rails and 12 good service rails as to the presence of phosphorous streaks in the zone of fissures. In many instances the nucleus of a fissure seems to be located in a phosphorous streak, and practically all the fissured rails examined contained these streaks. It is also suggested that phosphorus is better diffused in reheated blooms than in the direct rolled product. Discussed by Dr. Dudley, C. B. Bronson, G. M. Davidson, James E. Howard, and M. H. Wickhorst. Dr. Dudley presents some information as to the better behavior of reheated blooms. Mr. Wickhorst shows typical transverse fissures and deep etchings, and suggests similarity of origin between flakes in forgings and fissures in rails. Mr. Comstock's paper is abstracted in Railway Age, November 29, 1918. Both the paper and discussion are reviewed from reprints in Engineering News-Record, March 13, 1919, Vol. 82, p. 532. Dr. Dudley's discussion is abstracted in Engineering and Contracting, May 21, 1919, Vol. 51, p. 540.

Microstructural Features of Flaky Steel. By Henry S. Rawdon. Transactions of the American Institute of Mining and Metallurgical Engineers, Vol. 62 (1919), p. 246. Mr. Rawdon states that flakes originate as intercrystalline shrinkage cracks in the ingot and persist into the finished product as discontinuities, often associated with slag films. He also believes that the rate and distribution of cooling stresses have an important role in governing the defects.

Flaky and Woody Fractures in Nickel Steel Gun Forgings. By C. Y. Clayton, F. B. Foley, and F. B. Laney. Transactions of the American Institute of Mining and Metallurgical Engineers, Vol. 62 (1919), p. 211. The authors attribute flakes to overheating and non-uniformity of heat of the ingot, resulting in the incipient fusion of minute grains of highly segregated structure; the working of the metal flattens these grains into films. Thorough soaking through the critical range appears to effect decided improvement in physical properties, and reheating through this range resulted in effacing flakes from material very bad in this respect. These results appear significant in connection with the greater freedom from fissure in rails from reheated blooms and tend to emphasize Mr. Comstock's suggestions regarding the practicability of promoting diffusion of impurities through proper heating. In comparison with the deep etching of rail heads, the following is of interest. "In etching flaky steel for macroscopic examination it was noted that the flaky areas were attacked more readily than the normal steel and if the sample were permitted to remain long enough in the acid the flake area was eaten out and resembled a minute crack." This also seems suggestive. "That the damage which causes flakes is done after the ingot is poured is indicated strongly by an experiment in which two ingots were cast from the bottom through a common runner; one ingot made a flaky forging and there was no trouble from this source in the other." This article together with the work of Mr. Rawdon are discussed in the same volume of the Proceedings, p. 263, by Messrs. P. E. McKinney, J. A. Mathews, O. A. Knight, F. N. Speller, J. E. Johnson, A. A. Stevenson, J. S. Unger, H. Traphagen, and H. C. Boynton.

1920.

On the Shattered Zones in Certain Steel Rails with Notes on the Interior Origin of Transverse Fissures. By James E. Howard. Proceedings of the American Society for Testing Materials, Vol. 20, Part 2 (1920), p. 44. Mr. Howard presents a review of the work so far accomplished on shattered zones, but seems hardly prepared to consider this condition the basic cause of fissures. The paper is discussed by Messrs. Comstock, Rawdon, Job, and Wickhorst, all of whom seem quite satisfied that the fissure nuclei are identical with "shattering cracks." Abstracts and reviews of the paper and discussion are presented in the following. Iron Trade Review, July 1, 1920, Vol. 67, p. 22. Engineering News-Record, July 8, 1920, Vol. 85, p. 51. Iron Age, July 1, 1920, Vol. 106, p. 20. Chemical and Metallurgical Engineering, June 30, 1920, Vol. 22, p. 1189.

Some Deep Etching Experiments on Steel Rails. By G. F. Comtsock. Chemical and Metallurgical Engineering, December 1, 1920, Vol. 23, p. 108. A large number of samples of new rail accumulated in Mr. Comstock's laboratory for other purposes were deep etched to develop interior shattering if present. No shattered structure was found, but as Mr. Comstock states, the percentage of fissured rail is so small that absence of shattering in a much greater number of new rails would not be evidence against the theory.

Interstate Commerce Commission Report of Chief of Bureau of Safety for Year ending June 30, 1919. Mr. Borland seems to have some confidence in the connection between shattered zones and fissures, as well as the origin of the shattering in thermal conditions at the mill. Abstracted in Railway Age, February 13, 1920, Vol. 68, p. 500.

The Nature of the Defects Revealed by the Deep Etching of Transverse Fissure Rails. By Henry S. Rawdon. Proceedings American Railway Engineering Association, Vol. 21, p. 1219. Mr. Rawdon's work shows that the shattered structure cannot be caused by the etching solution, which some investigators had indicated as possible. By depositing finely divided iron particles out of suspension in kerosene on unetched rail sections previously magnetized, the crack locations appeared as lined by the orientation of the particles. After marking with a punch and removing the particles, etching developed typical cracks in every location. It was also possible to spread the crack sufficiently with a punch to render it visible under a miscroscope without etching. Fracturing through the crack as opened showed a break apparently exactly similar to a fissure nucleus.

Metallographic Features Revealed by the Deep Etching of Steel. By Henry S. Rawdon. Bureau of Standards Technologic Papers No. 156, issued March 19, 1920. This paper includes Mr. Rawdon's work as above on rails and extends the field over gun tubes, ball bearings, cast steel and wrought iron. Both the papers are reviewed and abstracted in Engineering News-Record, January 15, 1920, Vol. 84, p. 129, and Chemical and Metallurgical Engineering, March 17, 1920, Vol. 22, p. 505.

Interstate Commerce Commission Investigation of Chesapeake and Ohio Accident near Hardware, Va. Report by Chief of Bureau of Safety dated February 21, 1920, of accident on January 7, 1919. Report by Mr. Howard is embodied in which shattered zones are discussed in general connection with fissure failures. This report is abstracted in Railway Age, May 21, 1920, Vol. 68, p. 1466.

Transverse Fissure Rails on Atchison, Topeka and Santa Fe Railroad, Heat 41177. By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 21 (1920), p. 1079. Result of drop, tensile and etching tests and chemical analyses on a heat of rail removed from service on account of failure of one rail from transverse fissure. The drop tests revealed a number of growing fissures and some gray spots. The rails showing fissures and to some extent the rails with gray spots exhibited shattered structure on deep etching, while the rails from the balance of the heat were free from shattering.

Are the Nuclei of Fissures Cracks? By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 21 (1920), p. 1183. Pieces from fissured rails were heated to 1400 F. and quenched in water. If grain continuity extends through the fissure nucleus or gray spot, then the grain should be refined to a noticeable extent by this treatment. However, on breaking the pieces a total of three fissures and one gray spot were exhibited, and the grain of all appeared identical with the usual structure. This is good evidence of discontinuity of structure, or crack, in the rail.

Examination of Rails Long in Service for Relation Between Internal Stresses and Strains and Transverse Fissures. By W. C. Cushing. Proceedings of the American Railway Engineering Association, Vol. 21 (1920), p. 1189. A large number of rails ranging from 10 and 45 years in service were examined under the drop to disclose transverse fissures and none were found. Internal stresses of considerable magnitude were shown to exist and the thought is strongly developed that service in track cannot develop fissures unless it has defective metal to work upon.

What is Brittleness in Steel Rails? By M. H. Wickhorst. Proceedings of the American Railway Engineering Association, Vol. 21 (1920), p. 1229. Various classes of brittleness are analyzed and great stress is laid upon the necessity of drop testing with the head down, that is in tension, so as to prove the duitility in the zone of fissures.

Review of Work on Transverse Fissures. By Dr. P. H. Dudley. Proceedings of the American Railway Engineering Association, Vol. 21 (1920), p. 1240. Reviews the work of Cushing, Waring, and Wickhorst and states that his own laboratory is proceeding with extensive tests of the usefulness of the magnetic survey as a test on new rails for soundness. The conductivity of metal to magnetic flux appears to bear some relation to the interior structure in degrees capable of registration as a considerable variation at different points on a rail bar. The interpretation of the result is not as yet clear.

The Relation of Shattered Steel in Fissured Rails to the Mill End of the Rail. By M. H. Wickhorst. Rail Report No. 90, American Railway Engineering Association Rail Committee, July, 1920. Will appear in Proceedings, Vol. 22 (1921). Shows that shattering cracks do not extend nearer than one-half inch to the hot sawed end of the rail. This is a strong indication that the crack develops on the hot bed as a shrinkage crack.

REPORT OF COMMITTEE XXII—ON ECONOMICS OF RAILWAY LABOR

C. E. Johnston, *Chairman;*
W. J. Backes,
A. F. Blaess,
B. M. Cheney,
C. C. Cook,
L. E. Dale,
John Evans,
R. H. Ford,
L. C. Hartley,
J. L. Haugh,
C. H. Stein, *Vice-Chairman;*
T. T. Irving,
R. E. Keough,
E. R. Lewis,
R. M. Pearce,
W. H. Penfield,
John C. Sesser,
J. R. Sexton,
Earl Stimson,
R. C. White,

Committee.

To the American Railway Engineering Association:

The following subjects were assigned to the Committee on Economics of Railway Labor and report thereon is submitted herewith:

1. Report on plans and methods for obtaining railway labor.
2. Study and report on methods for training and educating employees in engineering and maintenance work.
3. Study and report on standard methods for performing maintenance of way work for the purpose of establishing units of measure of work performed.

The subjects assigned are identical with those your Committee had under consideration during 1920; progress having been reported at the last convention on items one (1) and two (2).

The work of your Committee the past year has, to a large extent, embraced a study of the data assembled during 1920, and the coördination of certain well-defined principles and practices in order to formulate conclusions that may be helpful to the railways in solving their individual as well as general labor problems.

ACTION RECOMMENDED

1. The Committee recommends that the conclusions in Appendices A, B and C be approved and published in the Manual.

Respectfully submitted,

The Committee on Economics of Railway Labor,

C. E. Johnston, *Chairman.*

Appendix A

(1) PLANS AND METHODS FOR OBTAINING RAILWAY LABOR

W. H. PENFIELD, *Chairman;*
JOHN EVANS,
R. H. FORD,
J. L. HAUGH,
E. R. LEWIS,
J. R. SEXTON,

Sub-Committee.

Discussion

The problem of furnishing labor for railway service is complicated by fluctuations in the available supply in labor markets, by the seasonal nature of track work, and especially by that class of extensive improvements usually termed construction work.

Weather conditions determine the months in which outside work can most economically be done for practically all railroads in the United States. In the northern states, both east and west, this work is difficult and expensive if undertaken during the months December to March inclusive, while the ground is frozen or covered with snow. In the southern states it is expensive if done during the rainy season.

For this reason, it seems impracticable to recommend a country-wide plan for the permanent employment of laborers in the maintenance of way department, but consideration is recommended for a much broader, all-year program of maintenance work and permanent force wherever conditions permit.

Labor may be divided into four classes:

Native White,
Negro,
Mexican,
Other Foreign.

For the South and Southwest the negro and Mexican make the most desirable maintenance laborers. For the East, North and Northwest, the native white is the most desirable laborer when available. The native white is generally intelligent, requires less supervision and is more easily trained for permanent work and for promotion.

The native white or hobo is the best extra gang laborer, when obtainable, but where it is necessary to provide boarding camps for them, they should ordinarily be used in gangs of thirty or more on account of the expense of maintaining smaller camps. Care should be taken to see that more camps are not operated than can be kept full to avoid an excessive turnover and constantly disorganized gangs.

The foreign laborer is desirable for section work where native white labor is not available locally and where the section labor must be imported. Foreign labor is also desirable for extra gangs where work requires a full organization each day, or where it is impossible to hold a gang of native white laborers.

For the purpose of this report, railway labor in the maintenance of way department will be considered in two classes; first, permanent employees; second, temporary or seasonal employees:

Permanent Employees

(a) Under this heading should be classed all employees of the fixed establishment, who must have been in the service of the railway company a minimum length of time (six months to a year) to entitle them to such consideration.

(b) Permanent employees should be selected according to physical and mental qualifications, merit and ability.

(c) No employee should be accepted for permanent employment until he has passed a physical examination. Temporary employees, who are to be retained permanently, should be given such an examination before being permanently assigned.

(d) Permanent employees, in so far as possible, should provide their own living accommodations.

(e) Permanent employees should be selected with due consideration to their fitness for promotion. Appointments to higher positions should preferably be made by promotions.

Temporary Employees

(a) Under this heading should be classed all employees who are engaged for seasonal or special work and whose service will be terminated as soon as the work is completed.

(b) Wherever possible, laborers should be procured locally by the Foreman, preference being given to former experienced and desirable employees.

There are localities where it will always be desirable to import men, due to industrial competition, class of local labor available, etc. If satisfactory labor is available locally, the Foreman should be held responsible for procuring and retaining such men as he is authorized to work, and also for the character of the men he employs.

(c) Recruiting and care of such maintenance of way laborers as cannot be procured locally by the Foreman should be in charge of a company employee or officer. Such officer or employee may devote all of his time, if necessary, to labor matters. The scope of his duties and extent of his organization, if any, should be determined by the Management of the individual road. In so far as labor matters are concerned, he should work under the supervision of the officer who is directly responsible for the execution of maintenance of way or construction work. This may be the Chief Engineer, Engineer Maintenance of Way, General Roadmaster, General Superintendent, General Manager, Vice President, or such System Officer as directs or handles the work.

On roads where a Personnel Department or System Labor Department is maintained, the work of the Maintenance of Way Labor Officer should coördinate with such system plan.

The Labor Officer should be fully informed at all times and as far in advance as possible of all scheduled work. He should advise his superior officer as to forces available and terms under which they can be procured. His advice and his recommendations will be valuable in planning work, both as to the time when it should be undertaken and the extent or amount of work that can be successfully prosecuted under existing conditions.

The Labor Officer should keep in constant and intimate touch with labor centers and other employers of labor, especially other railroads and industries. He should work with a view to coöperating in the transfer of labor released by one company and required by another. He should keep the names and addresses of all prospective employees and the class of work they desire. He should also inform them as to the probable date of employment and the location of the work. When men are employed, the labor officer should attend to all details of shipment, provide transportation, arrange for equipment, see that men reach their destinations and are placed satisfactorily at work. He should at all times have an intimate knowledge of conditions affecting maintenance of way labor, employed or to be employed.

(d) In procuring labor, the Labor Officer should take advantage of every legitimate source for procuring men, paying particular attention to voluntary applications of individuals or groups of men. He may sometimes find it desirable to maintain an employment office or offices to accomplish results.

(e) For the successful recruiting of maintenance of way laborers, it is often necessary to transport men free of charge over the lines of the company employing them. This practice is recommended.

It will usually be possible to recruit sufficient labor for each company's requirements from cities on their own lines and it is not recommended that any exchange transportation be issued for shipment over foreign lines.

It is recommended that return transportation over the employing company's lines be given laborers who remain on the work until the close of the season.

Transportation or passes should be issued only under well defined rules. Passes should not be furnished until men are ready to take the train. The practice of giving an agency, foreman or interpreter a pass with which to solicit labor on the street is bad.

Regular officers authorized to issue transportation should write passes for labor shipments. Such passes, however, should only be issued on request or advice from the Labor Officer. Passes for shipments which are to be made from points other than where the Labor Officer has representation should be written by the nearest Superintendent. This will usually prevent moving men away from a job from which they should not be taken.

(f) When laborers are to be housed and fed the Labor Officer should supervise the equipment and operation of camps and see that proper sanitary precautions are observed. He should also see that men are comfortably housed, that good, wholesome food and water are provided, and that their interests are properly protected.

CONCLUSIONS

1. The question of obtaining railway labor is broad and one deserving of careful consideration and organization.

2. In the interest of efficiency and economy maintenance employees should have the necessary mental and physical qualifications.

3. Best results may be obtained by providing some officer or some organization to supervise the selection and care of employees.

4. The living conditions of employees should be sanitary and comfortable. Food should be wholesome and of sufficient quantity, and work so regulated as not to be injurious to health.

5. Every encouragement, consistent with economy and efficiency, should be given to permanent employment throughout the year.

6. To avoid abuses, free transportation for railway labor should at all times be within the control of regularly delegated officers or employees.

Recommendations

That the conclusions reached by your Committee with reference to Item (1) be adopted and published in the Manual.

Appendix B

(2) REPORT UPON METHODS FOR TRAINING AND EDUCATING EMPLOYEES IN ENGINEERING AND MAINTENANCE WORK

A. F. Blaess, *Chairman;*
B. M. Cheney,
L. C. Hartley,
T. T. Irving,
John C. Sesser,
R. C. White,
Sub-Committee.

The study your Committee feels should be considered in the following light:

(A) Training and educating engineers or employees in the Engineering Department in maintenance work; and,

(B) Training and educating employees (other than engineers) in the Maintenance of Way Department, looking to greater economy and efficiency as well as promotion.

Your Committee has found it impracticable to outline a definite program of procedure that might be applied to all roads, due to the inherent personal equation of employees involved, together with the variation in practices and policies ever present in railroad service. It seems, therefore, we can only in a general way deal with the question at hand. The earnest coöperation and sustained interest of all concerned is the first essential to success.

DISCUSSION

(A) Training and Educating Engineers or Employees in the Engineering Department in Maintenance Work.

It is desirable that engineers in the maintenance department be graduates of some good technical school, but these positions, however, should not be limited to graduate engineers. To limit these positions to graduate engineers would in many instances drop the bars against young men who display ambition to follow engineering. When on account of finances young men are unable to take a full course at an engineering university, and study engineering with some good correspondence school or university extension course, they deserve consideration. Such men understand that their success depends upon their obtaining the necessary knowledge of their profession. The engineer who is obtaining his theory by private study should have as good knowledge of the theory of his profession as his more fortunate co-workers who have had the advantage of a college course. There have been numerous cases where university graduates were unable to make practical application of their knowledge, and we do not think we should exclude from consideration the man who obtains his theory by other means.

Every railroad organization has its own ideas and methods on the education and training of young engineers for positions of greater responsibility. It should, however, be possible to agree on a selection of these for general use.

Good results may be obtained by carrying on an educational campaign through periodical meetings for the purpose of exchanging views through the medium of papers, reports and discussions. This can probably be best brought about by organizing an association modeled somewhat along the lines of the A.R.E.A. Membership should be offered all officers above the ranks of supervisor of bridges and buildings, supervisor of track, supervisor of water service and supervisor of signals, including assistant engineers in the maintenance of way department. This association should appoint committees following, as far as possible, the same line of research work as done in the A.R.E.A., modified as local conditions might suggest.

The young engineer should be required to study and thoroughly familiarize himself with standard plans and practices, with maintenance of way reports, and with the rules, general instructions, etc., governing the maintenance department. He should also be encouraged to familiarize himself with proceedings of the A.R.E.A. and recommended practices of their Manual. It should be the endeavor to arouse and sustain the interest of young employees by explanations of work assigned, in order that they may be able to appreciate the relation of their particular work to the general maintenance scheme.

An incentive should be offered employees to work by encouraging them to take additional responsibilities. Every man should be trained for the next higher position. Probably the best method is to rotate the field and office work, if possible, showing a man his mistakes immediately upon completion of each assigned job. The young employee should be encouraged to study maintenance methods from the standpoint of economics, with the idea of developing an analytical viewpoint—a valuable asset in maintenance of way work.

There should be practiced a systematic rotation of service for the members of the engineering corps, to include surveying and field work, masonry inspection, building inspection, supervision of construction and work in drafting and designing. After the young engineer has had sufficient experience in office and field work, he should be transferred to a position which will give him experience and training in the handling of men and practical maintenance work.

A fixed minimum engineering corps should be maintained throughout the year with definite lines of promotion, to the end that the employee will have an incentive to continue in the service of the railroad company.

The young engineer should be required to attend division staff meetings and take part in discussions, thereby becoming familiar with the various operating matters discussed.

The Division Engineers, or corresponding officers, should take a personal interest in the education and development of young engineers, taking them over the road as frequently as the opportunity presents itself on their inspection trips, discussing with them the various features of the work they come in contact with, encouraging them to ask any questions and offer any suggestions that might occur to them, thereby broadening their views on the general conduct of maintenance work.

It is believed the positions of supervisor of track, supervisor of bridges and buildings, supervisor of signals and inspectors should be filled from the engineering corps on an equal footing with other employees.

(B) Training and Educating Employees (Other than Engineers) in the Maintenance of Way Department, Looking to Greater Economy and Efficiency as Well as Promotion.

A great many railroad officers are of the impression that track work can be efficiently performed by the most inexperienced common labor. This is a mistake. The productive efficiency of experienced trackmen is much greater than that of green and inexperienced men, and they should, as far as practicable, be given steady employment and encouragement by promotion when the opportunity presents itself.

It is recognized that railroads, generally speaking, cannot work a uniform force the year around. On many railroads, particularly northern and western roads, climatic conditions are such that the heavy maintenance work must be performed during the summer season, and it would be uneconomical to keep a uniform force during the entire year. However, it is necessary on all railroads to maintain a small force for maintenance work through the winter and the men who are retained in the service should be the older, in point of service and experience, and such new men that are promising and display an interest in the work.

It has been the practice on nearly all railroads to pay all track laborers, regardless of their length of service and experience, a flat rate of pay. The old and conscientious employee is certainly more efficient and, therefore, is entitled to more pay than a new man without training and experience in track work. It therefore seems to your Committee that instead of paying track laborers a flat rate, the rates should be graduated and pay increased in proportion to the length of time in service and his relative efficiency. This has been the subject of discussion from time to time, and it seems that the railroads should be able to work out a system whereby the application of a graduated rate of pay would be practicable and ultimately productive of greater efficiency. By offering track men an increase in pay with increase in knowledge and productivity, as well as length of service, there will exist an inducement for men to fit themselves for the position of foremen. It is the practice in some of the sub-departments of the maintenance of way department, namely the bridge department, signal department and water service department, to have graduated pay for the employees, and we feel that it would be advisable to adopt a similar practice in the track department among the class generally known as common labor. Your Committee would suggest that at least one man be assigned to each gang to be known as "first trackman," his rate of pay to be three or four cents per hour higher than the others. After they have had the necessary training and experience, they should be advanced to assistant foremen or foremen. Should these men fail to show a reasonable aptitude for the work, they should not be retained in such positions, the fundamental idea of such an arrangement being to retain only such men in these positions as will eventually qualify for advancement.

The foreman is required to have had a well rounded practical experience in track work. He should have at least a common school education. He must be energetic and must constantly devise methods to hasten the work and eliminate lost motion. He must be a man with a great deal of patience, but one who is firm and exacts strict obedience, at the same time gaining the good will of his men and treating them as he would like to be treated himself.

Roadmasters, Supervisors and other officers in charge of maintenance, in going over the road, should closely observe the performance of their men. They should take a personal interest in them, and be on the lookout for men in the ranks who display exceptional ability in handling their work. When such men are discovered they should be developed by placing them under experienced foremen, shifting them among different foremen and different classes of work, as opportunity offers. These men should be furnished books of rules and instructions, and invited to attend periodical meetings of the foremen held by the supervisor. Their knowledge of maintenance work should be stimulated and encouraged in every possible way.

Excellent results can be obtained by holding periodical meetings for the foremen to be presided over by Supervisors or corresponding officers. A well planned system of discussion appeals strongly to the man of limited education. Previous to these meetings, the Supervisor should announce one or two subjects to be discussed, in order to allow preparation and assure thoroughness. Conclusions should be drawn for the benefit of the whole organization. It is thought that better results would be obtained by this method than from having a general discussion on many subjects. It is not thought that large meetings should be held to begin with, but that in most cases meetings should be limited that each attendant would have an opportunity for oral discussion. The Superintendent and Roadmaster, or corresponding officers, should attend these meetings, as the interest of the superior officers in, and their personal association with, the men in the ranks is important and far reaching in training the men for higher positions.

It is believed the use of motion pictures for the purpose of illustrating methods of work and ideal results will be found the most valuable of all methods. When it is considered that a rule, an order, or a standard plan on a large system must reach from 500 to 2,500 foremen and 50 to 75 Roadmasters or Supervisors, and in reaching its destination must pass through several hands, it will be appreciated that before it finally gets to the section foreman it will have been explained and presented in several ways by several different men, probably no two of them will give equal value to the essential features, with the result that the impression finally conveyed to the lowest man in the rank may not be the impression intended.

It is felt that proper and accurate transmission of instructions and information is a primary and important problem in any plan of education. It seems that with proper use, the motion picture is adapted to do a great deal to overcome deficiencies from the cause above mentioned. This method of instruction has been in use on some railroads in other departments, and it is thought that a railroad of large mileage could well afford to take a car or two and fit up a motion picture outfit, with selected views and a definite course of instruction. It is thought necessary that a man be selected to accompany the pictures who would be qualified to explain the various kinds of maintenance of way work. Such a man would visit the different headquarters, hold class meetings and illustrate his points with magnified pictures of standard plans of work being done, such as laying rail, applying and tamping ties, as well as other important phases of maintenance of way work, and this would do a tremendous amount of good and be of inestimable aid.

The foremen and other maintenance of way employees should be encouraged to subscribe to literature and periodicals pertaining to maintenance of way and structures. In fact, your Committee feels that a railroad company could well afford to subscribe to such literature and have it furnished to all foremen in the maintenance of way and structures department.

Suggestions should be invited and encouraged from employees, not only pertaining to their own line of work, but for the good of the service as a whole, thereby letting the men know they are an important part of the machinery.

It is believed tangible results would be secured from the development of a pension system to provide for employees who have grown old or become incapacitated in the service. This system would not only greatly help to retain men, but would encourage them to become sufficiently interested in their work to take a personal pride in their road, which in time would tend to increase loyalty and efficiency.

Employees should be encouraged to take a course in some good correspondence school, preferably some "Railway Educational Bureau." At such a school they will get the fundamental ideas not only of track work, but of accounting and various other features so important for the development of men to positions of foremen and higher supervisory positions.

CONCLUSIONS FROM DISCUSSION OF SUBJECT (A)

1. Engineers trained in maintenance work, are essential to an efficient organization.

2. The systematic training of young engineers for maintenance work should be carefully undertaken, and if in due course they do not display

necessary qualifications to combine practical and technical training with ability to organize, direct and supervise work, they should not be retained in this branch of service.

3. Training of young engineers in maintenance work may best be accomplished by rotation in service.

4. It is essential to the training of young engineers that they familiarize themselves with the rules and practices of the operating and accounting departments.

5. In the interest of an efficient organization it is desirable to maintain a fixed minimum engineering force throughout the year.

6. It is desirable that there be practical coöperation between railway managements and schools and colleges offering technical courses for the better preparation of young engineers entering railway service.

CONCLUSIONS FROM DISCUSSION OF SUBJECT (B)

1. A thorough and systematic method of training employees in maintenance work is essential for efficiency and for promotion to advanced positions.

2. In promotion, merit and fitness should govern. Employees having necessary qualifications should be given every legitimate opportunity and encouragement to obtain necessary training and experience.

3. To accomplish best results, methods should be installed to promote individual effort and interest. Personal contact and personal interest shown on the part of the supervisory forces will go far to bring this about.

4. Employees should be encouraged to seek further education from outside sources on general principles of railway operation, such as through correspondence, night schools and periodicals on railway maintenance.

Recommendations

That the conclusions reached by your Committee with reference to Item (2) be adopted and published in the Manual.

Appendix C

(3) REPORT ON STANDARD METHOD FOR PERFORMING MAINTENANCE OF WAY WORK FOR THE PURPOSE OF ESTABLISHING UNITS OF MEASURE OF WORK PERFORMED.

EARL STIMSON, *Chairman;*
W. J. BACKES,
C. C. COOK,
L. E. DALE,
R. E. KEOUGH,
C. H. STEIN,
Sub-Committee.

The American Railway Engineering Association from its beginning in 1899 until 1917 devoted practically its entire time and effort, through some twenty standing committees, to the study and establishing of plans and specifications for the materials and structures that are used in the construction and maintenance of railroads. As a result we have complete plans and specifications embodying the most advanced state of the art for the various items of materials that make up railroad structures and in many instances for the assembled structures. The use of materials is readily susceptible to control. The economics of materials, therefore, seems amply provided for.

The cost of materials, however, averages not more than one-half the cost of construction and will run as low as 35 per cent of the total cost of maintenance. The remaining percentage of maintenance and construction costs is largely that of labor and it offers a most prolific field for the application of economies. This fact was finally recognized by the Association when it created the Committee on "Economics of Railway Labor."

Maintenance of Way expenditures and consequently the amount of labor employed fluctuates during the year on account of the seasonal character of the greater part of the work, principally the track work, and other fluctuations from year to year rise and fall in unison with the financial conditions.

Any form of budget that may be adopted has for its determining factor this same financial condition. A carefully prepared budget covering a year's work, although approved, is subject to modification from month to month, often causing abrupt and violent readjustment of force.

Although these are natural phenomena, they are none the less disconcerting to the maintenance engineer, and the more so to the supervisor and the foreman who bear the brunt of the effects of this instability.

All this results in lack of uniformity of force, the demoralization of an everchanging personnel and the impossibility of that continuity of program so essential to economy.

Work done under such conditions entails great waste, which added to the waste arising from misdirected effort and useless and ineffective motion due to lack of proper methods and gang organization, amounts to a large and an incalculable sum. It is sought to overcome this waste and effect a large saving to maintenance costs by introducing a system of standardizing methods of performing the various items of work, outlining the proper gang organization for such work, establishing time schedules or units of measure of the work to be performed and keeping of records of the performance for comparison with the standard to determine the rating of the performance.

On account of the diversity of conditions under which work is done on the various railroads and in the various parts of the country, it is not practicable for the Committee to attempt to establish for general application standards of performance for each item of work. The Committee submits certain principles, supplemented by sufficient detail, which are flexible enough for application to any condition of work or size of force.

These are submitted in the following outline of methods for standardizing the performance of the various items of Maintenance of Way work for the purpose of establishing units of measure of work performed. For the present report the application is confined to track work, although equally applicable to all kinds of work.

The principles which have been so successfully used in shop operations, namely, the principles of so-called "Scientific Management," are the basis of this plan. It embodies both descriptions of standardized methods and standardized schedules for the measurement of the units of work performed.

For the purpose of illustrating the application of this plan, examples of methods, schedules and forms of reporting are submitted as an essential part of this report. It is not intended that these examples are necessarily to be taken as the standard to be followed, but rather as guides to those who seek to apply this plan to their own uses.

The main features of this plan are as follows:

(1) Standard methods and time schedules for each item of work.

Examples of typical methods and schedules are given as:

Exhibit "A"—Method—Making Time Studies.
"B"—Method—Renewing Rail Out of Face.
"B-1"—Schedule—Renewing Rail Out of Face.
"C"—Method—Cross-Ties—Renewing.
"C-1"—Schedule—Cross-Ties—Renewing.

(2) Instructions to foremen to enable them to submit accurate reports of performance.

An example of typical instructions is given as:

Exhibit "D"—Instructions for Reporting and Distributing Track Work Time Charges.

(3) Closer supervision by means of planning and dispatching the work in advance.

Examples of typical forms are given as:

Exhibit "E"—Planning Sheet.
"F"—Work Order or Dispatching Sheet.

(4) Sample forms for the notation of records and performance for comparison of results.

Examples of typical forms are given as:

Exhibit "G"—Daily Record of Track Work Performance.
"H"—Monthly Record of Track Work Efficiency.

Taking up these various features in order.

(1) Standard Methods and Schedules

Standard schedules, or units of performance, should be established with great care, as it is essential that they be correct and that the organization of the gang and method of doing the work are the best that can be worked out.

The standard performance, or 100 per cent efficiency, is the output of a first-class gang working at a speed which can be continuously maintained without physical harm to the men, following an approved method of doing the work and consisting of the most effective number of men for the kind of work to be done.

To arrive at the 100 per cent standard, first-class gangs are to be selected and detail time studies made of the performance, the time studies being divided into as many moves and as much detail as possible in order that the various studies may be compared in detail and a standard method worked out which will eliminate all unnecessary moves. If it appears that an improvement can be made, the organization of the gang and the method of doing the work should be altered and new studies made. When the most satisfactory organization and method has been found, a final detail study is made of the performance of the gang and this is established as 100 per cent efficiency and issued as a standard schedule. In this way schedules may be established for all of the more important items of maintenance work. A "Method for Making Time Studies" and a sample "Time Study Sheet" are shown in Exhibit "A."

In preparing such schedules it may at first be thought that, owing to the wide variation in conditions, there would be a number of items of work for which it would be impossible to work out standard schedules, but the study of performances will develop a remarkable uniformity in the output of gangs working under apparently widely varying conditions, and there are relatively few items of maintenance work which cannot be standardized. In cases where one standard schedule cannot be made to apply, as, for example, in ditching, a schedule should be made for the individual job and be based on previous records, performances under similar conditions, or observations after the work is started. For individual pieces of work of this kind, after careful study and planning of a method to be followed, a schedule or standard of output for 100 per cent efficiency should be established and the foremen's reports graded on this basis.

Going to and from work and clearing the track for passing trains, represents considerable lost time which is beyond the control of the foreman and men. This lost time is classed as detention, and studies should be made to determine the amount of detention for each gang. This detention is expressed in per cent of total time and, in grading the foreman's reports for comparison with the standard schedule, a credit of the detention per cent is allowed. On terminal and yard sections the detention is usually much more than on road sections.

(2) Instructions to Foremen

To form an accurate comparison of the performance of the various gangs, uniformity in the reports submitted by the foremen is necessary. Owing to the difficulty some foremen have in making reports, it is desirable to have all forms used by them as simple as possible.

A daily report by the foreman of time spent and the work done by each gang is necessary. Where there is in use a form of daily time report, it can readily be made suitable for this purpose.

It is, however, necessary that the distribution shown on the daily time report be made with care, so that each item of work can be correctly graded. To secure this result detail instructions governing the distribution and reporting of the time charges are required.

Typical instructions for reporting and distributing track work time charges are given in Exhibit "D."

(3) Planning and Dispatching

To outline the order of the work and to assign it to the gangs to follow in sequence, so as to reduce the loss of time consumed by the unnecessary movement of the gangs from place to place, a system of planning and dispatching is needed.

Early in the year the program of work for the season should be decided upon and charted on a planning sheet (Exhibit "E"), the proposed work being shown in yellow. Thereafter as the work progresses, monthly planning sheets are prepared; the completed work is shown in green and the monthly program in red. A few days before the close of the month the Division Engineer calls a meeting of the supervisors for the purpose of planning the work for the month. The work to be done, the location and the relative order in which it is to be undertaken is decided upon and shown in red on the chart. The quantity of work to be accomplished is computed from the standard schedules and the force allotted for the month. The direction in which the work is to progress, the date on which it is to be commenced and the calculated date of completion are to be shown on the chart.

The chart is prepared in duplicate, one copy to be retained by the Division Engineer and the other for the use of the supervisor. Upon his return to headquarters, the supervisor transmits the program to the foreman by means of work orders, giving him the program for the entire month, or any part of it, as he may see fit. For this purpose a work order, or dispatch book, is provided (Exhibit "F"). The book is bound in stiffback, note-book form, and contains 100 perforated leaves.

The work order is made out in duplicate, the carbon copy being filed on the dispatch board, serving as a ready reference showing the work being done by each gang and where working. The work order states the kind, location, amount of work to be done and the time to be consumed. Upon completion of the work the foreman dates and signs the order and returns same to the supervisor. The foreman is given a work order for all work to be done. This, however, does not relieve him of the responsibility of making unforeseen and emergency repairs.

(4) Forms and Reports

For the purpose of recording the performance of the gangs two forms are used—one, a Daily Record of Track Work Performance (Exhibit "G"), the other, a Monthly Record of Track Work Efficiency (Exhibit "H").

The result of each day's work as sent in by each foreman on the Daily Time Report is posted on the Daily Record Sheet, and the efficiency per cent of the day computed. For example: A gang of a foreman and nine men, working ten hours per day, holds a work order to renew ties without raising track. The schedule under which the work will be done is that given as an example of a Standard Schedule (Exhibit "C-I"), and is eight ties per ten hours. The foreman's daily report shows that his gang renewed 64 ties in 100 hours. The standard time required to renew 64 ties in stone ballast track not raised is 80 hours, whereas the actual time consumed was 100 hours. However, 10 per cent. of this was consumed by clearing passing trains and other delays chargeable to "Detention," leaving 90 hours actually devoted to effective work. On the Daily Record Sheet, under the heading of Renewing Cross-Ties, 80 is recorded as "Standard Time" and 90 as "Actual Time," indicating an efficiency of 89 per cent. All other work is recorded in the same way.

At the close of the month the "Monthly Record of Track Work Efficiency" is compiled from the totals of the "Daily Record." The monthly record shows the percentage of efficiency made by every gang on each class of work, the average of every gang on all work, and the average for the supervisor's sub-division—in other words, a detailed and an accurate record of the actual performance of every gang as compared with the Standard Performance. The "Standard" divided by the "Actual" gives the efficiency per cent.

Additional Supervision Required

The supervisors should not be required to handle the details of the operation of this system as it is impossible for them to do so in addition to their regular duties. Each supervisor should be given an assistant, who devotes his entire time to the study of standard schedules and methods, to the recording and study of performances, to the instruction of the foremen in regard to standard practice, and to checking in the field the reports of work done to guard against errors.

(5) Force Distribution

Incidental to standard methods in Maintenance of Way work is the feature which will provide for an equitable distribution of the available track force to the various sections. A procedure which the Committee suggests for consideration is the reduction of all features of track to the equivalent of one mile of first main track. A table of values, derived from actual costs extending over a period of years, for a main line division which was subject of special study, follows:

One mile of first main track equivalent to:

- 1.15 miles of second main track;
- 1.33 miles of third or fourth main track;
- 2.00 miles of branch line track;
- 2.00 miles of passing and thoroughfare track;
- 3.33 miles of yard tracks;
- 12 main track switches;
- 20 side track switches;
- 10 railroad crossings;
- 12 city street crossings;
- 25 to 50 county road crossings;
- ½ mile track pans;
- 4 miles ditches.

A form for the notation of these values per section and sub-division is shown in Exhibit "I."

For the purpose of elasticity in use of the above form to meet the changing conditions of various elements of the track, it is suggested that the condition of the main elements per section be stated monthly and a "Condition Per Cent" of the whole section determined. This result applied to the equivalent mileage of the preceding form (Exhibit "I") gives the equated mileage for the section. The ratio of the equated mileage of the section to the total equated mileage of the division determines the number of men to be allotted to that section from the total number of men allotted the division. A form for noting "Condition Per Cent" per section is shown as (Exhibit "J"). This form shows tentative relative values for certain elements of track as determined from an analysis of the records of previous years modified so as to meet the renewal program and other seasonal work.

This force distribution plan is a product of the application of standard methods and schedules, and is a development of the methodical direction and measurement of track work. It is described herein simply to indicate the form in which it may be developed.

CONCLUSIONS

The plan herein outlined and supplemented by the examples for illustrating its application, is based on the fundamental principles of good management.

It is a well-defined plan for maintaining contact with and directing the work of a class of labor which, by reason of the extended territory over which it is spread, is usually isolated and remote from that close supervision and direction so necessary to economic results.

It places available each day an accurate record of the performance of each gang, with its rating according to the established units of measure, for the use of the supervising officer in directing effort to increase the effectiveness of the gangs.

Recommendations

(1) That the main feature of this plan, as described in—
Section 1—Standard Methods and Schedules.
Section 2—Instructions to Foremen.
Section 3—Planning and Dispatching.
Section 4—Forms and Reports
and Exhibits "A" to "H" inclusive be adopted and published in the Manual.

(2) That Section 5—Force Distribution
and Exhibits "I" and "J" be received as information.

Exhibit "A"

METHOD FOR MAKING TIME STUDIES

Time studies are made: First, to find the proper time to allow as standard for any given piece of work; second, to find the best method of doing the work, as to number of men, organization, sequence of separate operations, proper tools, speed of work, etc. These features are all developed through analysis of the work, separating it into the different operations, timing each one separately several times, and considering the factors that make the quickest time possible.

Several time studies on each piece of work studied, are therefore necessary, as a single one may be misleading. The standard time is not the sum of the least time for all the operations, as in some instances these least times may represent some favorable conditions which only occur at long intervals or too strenuous work by the men for a short time, which could not be maintained continuously. The standard is the time in which the work to be performed can be done continuously by an industrious, trained and efficient gang.

In track work there are several different types of time studies:

1. When one man does the entire piece of work, as in Tightening Bolts.

2. When more than one man is required, a fixed gang is assigned and part are idle while the others work, as in Unloading Ballast from Hoppers.

3. Where more than one man is required, but where the working conditions are so elastic that no matter what size gang is provided, all the men can be worked, as in Laying Rail.

Case No. 1 is simple. The operations in a typical case being: (*a*) Preliminary Oiling, (*b*) Walking from one joint to the next, (*c*) Tightening each bolt in order, (*d*) Foreman's supervision. If the gang has but three or four men, the Foreman should work like the others when tightening bolts and no time be added for Foreman's supervision.

Case No. 2. The work train is a factor in the example described and a gang is usually detached for the work and sent with the train, hence, if delayed, the men are idle. In order not to delay the train the gang should be as large as can work effectively; if larger, a decided waste results, for the reason that the working space is restricted.

Under each operation the items of work which go on simultaneously are noted with the number of men engaged in each (see Sample Time Study, Exhibit A). The sum of the identical times used for each operation, except Foreman's time, equals the elapsed time, and the proposed elapsed time multiplied by the standard gang (including Foreman) equals the proposed standard time.

The Sample Time Study shows that 10 men were used but that it was seen 4 men on ground and 4 on cars would be ample and an 8 man gang was recommended. It will be noted that the standard times shown are not the lowest or the highest but are chosen as representing a good lively performance.

Case No. 3 is simple although the gang is larger. When a squad of men finishes one operation they are put on another and all may be kept busy if the Foreman and his assistants are capable.

The final standard time is made up of several simple time studies for, (*a*) Adzing, (*b*) Drawing spikes, (*c*) Lining out old rail, (*d*) Turning in new rail, (*e*) Placing joints, (*f*) Full bolting, (*g*) Full spiking.

As to each separate individual operation, the following questions should be decided before setting the proposed standard time:

1. Is the operation necessary?
2. Is it done in the best way?
3. Is it done in the least time consistent with continuous performance?

(Sample Time Study Sheet)

TIME STUDY ON UNLOADING STONE BALLAST FROM HOPPERS

Made on..............Division, Section 60, at......................., by J. Doe, date April 6, 1916; size of gang 10* men, 1 Foreman; weather, fair and cool.

Note: Quality of Workmanship. — Speed of Performance.

Average ....X.... — Average ....X....

Better than average......... — Faster than average............

Poorer than average........ — Slower than average............

Note if there was any idle time.

Give recommendation as to standard size gang.

Note any interruptions.

Operation No.	ITEMS OF WORK.	TIME STUDY No. 1.	TIME STUDY No. 2.	TIME STUDY No. 3.	PROPOSED STANDARD TIME.
1	Placing shoes..........	10:10 a. m. 2 min., 2 men	10:21 a. m. 1½ min., 2 men	10:32 a. m. 2½ min., 2 men	2 min., 2 men
	Removing shoes from empty...............	2 min., 2 men	1½ min., 2 men	2½ min., 2 men	2 min., 2 men
	Waiting to shovel down	2 min., 6 men	1½ min., 6 men	2½ min., 6 men	2 min., 4 men
2	Placing tie.............	2 min., 2 men	3 min., 2 men	1½ min., 2 men	2 min., 2 men
	Removing tie from empty...............	2 min., 2 men	3 min., 2 men	1½ min., 2 men	2 min., 2 men
	Waiting to shovel down	2 min., 6 men	3 min., 6 men	1½ min., 6 men	2 min., 4 men
3	Releasing drop bottoms	3 min., 4 men	2½ min., 4 men	5 min., 4 men•	3 min., 4 men
	Winding up drop bottoms (empty).......	3 min., 4 men	2½ min., 4 men	5 min., 4 men	3 min., 4 men
	Waiting to shovel down	3 min., 2 men	2½ min., 2 men	5 min., 2 men	....
4	Shoveling down.......	4 min., 6 men	4½ min., 6 men	3½ min., 6 men	4 min., 4 men
	Jarring down ballast (by men on ground)..	4 min., 4 men 10:21 a. m.	4½ min., 4 men 10:32 a. m.	3½ min., 4 men 10:45 a. m.	4 min., 4 men
	Foreman's Time.......	11 min., 1 man	11 min., 1 man	13 min., 1 man	11 min., 1 man
	Elapsed Time.........	....	....	....	11 min., 9 men
	Proposed Standard....	....	....	....	99 min.

* Recommend 8 men for this work.

• Delay by drop bottom sticking.

Exhibit "B"

METHOD: RENEWING RAIL—OUT OF FACE

The method outlined will be for the simplest conditions, *e. g.*, light curvature, no tie plates, new rail of same or heavier section, and both new and old rail laid with plain angle bars.

Special conditions varying from the above can be met by changing the organization to meet their needs.

The work preliminary to rail relaying consists of:

(*a*) Scoring or preliminary adzing to enable spikes to be drawn more readily.
(*b*) Drawing every third spike on one side.
(*c*) Starting the remaining spikes.
(*d*) Driving down stubs.
(*e*) Removing anticreepers.
(*f*) Driving tie plugs.
(*g*) Rough adzing.
(*h*) Setting up rail.

The above should be done the first thing in the morning and the organization should be as given below.

A typical organization is given for a 32-man gang, and this should be followed when the men are available. Another typical organization is given for a 22-man gang, which is less desirable, but may be followed when the gang cannot be filled to the larger number.

TYPICAL GANG ORGANIZATION FOR WORK PRELIMINARY TO RAIL LAYING, 32-MAN GANG

2 Men adzing around spikes to be drawn.
6 Men with claw bars drawing every third spike on outside of rail and starting remaining spikes on outside.
1 Man driving down stubs.
2 Men driving tie plugs every third spike.
4 Men rough adzing outside of rail base.
1 Man with small bar turning rail up for tong men to pick up.
12 Men with rail tongs picking up new rail and placing it on end of ties.
1 Man with small bar turning rail down on ties with head of rail toward and about 8 inches from the rail to come out.
1 Waterboy.
2 Foremen.

32 Men.

METHOD AND DISTRIBUTION OF GANG FOR PRELIMINARY WORK

The work is started by the adze-men cutting around the spikes. They are followed by the claw bar men, who should be spaced one man to a rail and instructed to pull every third spike on the outside of the rail and start the remaining outside spikes so that they may be readily pulled when the track is opened. Each man on completing work on the rail assigned him should move to the sixth rail ahead and continue drawing every third spike and starting the remaining spikes. This space interval should be maintained continuously.

Following the claw bar men, one man drives down the stubs of any spikes which may have broken and removes anticreepers from old rail, two men plug the old spike holes in every third tie. Four men immediately follow doing all necessary rough adzing to save time of adze-men who level rail seat after old rail is turned out.

Working about opposite the adze-men, one man with a small bar turns up the new rail on its base so that it may be readily picked up by the tong men. Following the adze-men, twelve men with rail tongs pick up the new rail and place it on its base on the ends of the ties, one man with a short bar turns the rail down on its side so that the head of the new rail is towards and about 8 inches from the rail to come out.

One Foreman should supervise the work of the claw bar men, adze-men, etc., and the other, work of the tong men. One water boy supplies the entire gang.

The rail must be placed on the end of ties with care and accuracy; the end of the first rail so placed must be exactly opposite the end of the last new rail laid. On tangents an allowance for expansion should be made about every fifth rail. On the outside rail of curves additional spacing is necessary in setting up the new rail, whereas on the inside rail an occasional lap to be allowed on curves depends on the degree of curvature.

The above organization should do all preliminary spike pulling and set up from 225 to 230 rails before 10.00 a. m.

The preliminary work having been completed the organization of the gang is changed to meet the requirements for laying the new rail. The following is the gang organization for 32-men gang:

3 Men with claw bars pulling remaining spikes on outside of rail.
1 Man pushing truck loaded with tools, etc.
2 Men throwing out old rail.
2 Men driving tie plugs.
3 Men adzing and cleaning rail seat, after assisting in starting out old rail.
2 Men with claw bars starting inside spike after old rail is thrown out.
2 Men turning new rail to place and applying expansion shims.
1 Man holding new rail to inside spikes for spiking.
1 Man tacking three spikes per rail.
2 Men putting on angle bars and starting one bolt with fingers.
4 Wrench men putting in and tightening two bolts to each joint.
4 Spikers driving at least every other spike.
1 Water boy.
2 Flagmen.
2 Foremen.

32 Men.

METHOD AND DISTRIBUTION OF GANG FOR LAYING THE RAIL

Traffic in both directions must be protected by flagmen as prescribed in the Book of Rules.

Three men with claw bars pull the remaining outside spikes, each man taking one rail length, upon the completion of which he moves to the third ahead and continues pulling all outside spikes. As soon as a joint has been removed, the spikes pulled for three rails, nine men equipped with bars, commence throwing the old rail out over the new rail. When one rail length has been thrown out the weight, overhanging the new rail, assists in throwing out the old rail to such an extent that two men can continue the work and the others are divided as follows: Two men drive tie plugs in remaining spike holes; three men finish adzing and clean rail seat; two men with claw bars start inside spikes after old rail is thrown out, lifting them a sufficient distance to readily admit the base of the new rail.

Two men roll rail into place by means of small bars inserted in the bolt holes. The men work at opposite ends of rail; the man at the rear end of the rail rolls the rail over so that the base of rail is toward the center of the tracks; the man at the front end of the rail is in the direction of laying, then gives it another turn so that the rail stands on its base just outside of the inside of spikes. The rear man carries a small bucket containing 25 or 30 expansion shims, and as soon as rail is in place inserts shim while front man with bar forces rail back to contact with shim. Two men follow, one with bar holds the rail close to the inside line of spikes while the other tacks it in place with spikes at the center and quarter points.

The rail now being in the proper position in track, two men place the angle bars and insert the end bolts in the direction of traffic, the nut being run on the finger threads only. Four wrench men follow applying one more bolt per joint and tightening all bolts applied. If four hole angle bars are used the preliminary bolts should be numbers one and three in the direction of traffic and in six hole angle bars numbers one and four in the direction of traffic. The wrench men are followed by four spikers driving spikes in two of every three ties.

The gang is preceded by one man with push car containing surplus tools, bolts, nut-locks, compromise joints, etc.

One water boy supplies the entire gang and two Foremen supervise the work. The run having been completed and track closed the entire gang drops back on full bolting and spiking.

The above gang if given the track for an hour or more should average 75 rails per hour. For a period of 30 minutes, the gang should average a rail a minute. For any period less than 20 minutes, it is not advisable to open the track unless the work is being done in a congested district, in which case it may be necessary to break the track for a period less than 20 minutes.

ORGANIZATION OF GANG FOR OTHER CONDITIONS

To meet other conditions than those outlined above additional men must be added to the gang. All special conditions and combinations of various type of joints, etc., cannot be covered by illustrations; those commonly met with are given below.

Example No. 1 is that described in detail above and is the basic gang for two Foremen and 30 men.

Example No. 2. If the new rail is laid with Continuous joints add two men for additional joint adzing. Total gang, two Foremen and 32 men.

Example No. 3. Should the old rail coming out be laid with Continuous or depending flange joints, add two men for throwing out old rail at joints, and for Continuous or Weber joints, add one man for shimming old joint ties. Total gang, two Foremen and 33 men.

Example No. 4. If any type of depending flange joint is used on the new rail, add one Foreman and 20 men to respace and tamp joint ties. Total gang, three Foremen and 50 men.

Example No. 5. If old rail is tie-plated and new rail of a heavier section, requiring the renewal of all tie plates, add two Foremen and 30 men, which would make a total of four Foremen and 60 men.

The gang organization shown above may be combined in any way to meet the varying conditions outlined.

Under some combinations of conditions, the gang required becomes too large to be handled as a single rail gang. When this occurs the gang should be split up into smaller individual gangs. If, for instance, conditions are as shown under Examples 4 and 5, gang required would be five Foremen and 80 men, which would be difficult to handle and should be divided into smaller independent gangs.

For the purpose of describing the method, it has been assumed that the outside line of spikes will be pulled and the inside will remain; the method, however, applies just as well when the inside line of spikes is pulled and the outside line remains.

TYPICAL GANG ORGANIZATION FOR 22-MEN GANG

PRELIMINARY

1 Man adzing around spikes to be drawn.
3 Men with claw bars drawing every third spike on outside and starting remaining spikes on outside.
1 Man driving tie plugs.
1 Man turning rail for tong men.
12 Men with rail tongs.
1 Man turning rail to place on ends of ties.
1 Man distributing bolts, nut-locks, spikes and tie plugs.
1 Water boy—assisting adzer.
1 Foreman.

22 Men.

DURING RUN

2 Men with claw bars pulling remaining spikes.
2 Men throwing out old rail.
1 Man with claw bar starting inside row of spikes.
1 Man driving tie plugs and also driving down stubs.
1 Man cleaning rail seat and helping move rail longitudinally.
2 Men adzing.
1 Man turning in rail and getting expansion.
1 Man holding rail for spiker who tacks three spikes per rail.
1 Man spiking as above.
2 Men spiking two of every three ties.
4 Men applying joints with two bolts and tightening.
2 Flagmen.
1 Water boy, pushing truck with tools, etc.
1 Foreman.

22 Men.

DIRECTION OF LAYING

Rail should be laid with the current of traffic for the reason that the rail on curves is usually badly curve worn, and when it becomes necessary to make a connection on the high side of a curve there is a bad lip between the old and new rail which, for safety, should be in a trailing position.

MAKING CONNECTIONS

One of the quickest methods of cutting a rail for making connection is as follows:

The location of the cut having been determined, the old rail beyond this point should be full spiked. Score deeply the inside and outside of the base with a rail cutter, then place a claw bar between the webs of the two rails to give additional firmness. Men with bars line out old rail and hold in this position while one man with spike maul strikes the outside base. The rail will usually break at the first blow. Compromise joint is then applied and connection completed by full bolting and spiking.

Exhibit "B-1"

SCHEDULE: RAIL—RENEWING, OUT OF FACE

TIME DISTRIBUTION BASED ON TEN RAILS, SIX HOLE PLAIN BARS REPLACING FOUR OF SIX HOLE PLAIN BARS

OPERATION No.	OPERATION.	MINUTES FOR 10 RAILS.
1	Adzing before drawing spikes	43
2	Setting up rail	90
3	Drawing one line of spikes	90
4	Lining out old rail	60
5	Plugging spike holes	25
6	Adzing	50
7	Cleaning rail seat	18
8	Driving down stubs and cracking up remaining spikes	18
9	Turning in new rail	28
10	Distributing bolts, nut locks and spikes	20
11	Placing splice bars, and full bolting	140
12	Full spiking	110
13	Uncoupling old rail	110
	Two flagmen during runs	84
	Water boy—one for gang of twenty men	44
	Foreman—one for gang of twenty men	44
	Total time for ten rails	974
	Total minutes for one foot	2.95
	Standard Schedule, Hours per 33-ft. Rail	1.623

If any of the above items are not performed, subtract corresponding time with an allowance for supervision from totals and figure revised standard time.

SPECIAL CONDITIONS

Use of Angle Bars with Depending Flanges:

A—If respacing of ties is necessary on this account, grade the work by Schedule for Tie Respacing, counting each tie as one-half tie, if but one end of the tie is moved.

B—No additional time except what is described above is to be allowed for laying rail with depending flange joints.

C—When rail being *replaced* has bars with depending flanges, add thirty minutes to above itemized schedule and

Standard Schedule, Hours per 33-ft. Rail will be: 1.673.

Use of Continuous Bars:

A—When rail is being laid with Continuous bars, add seventy minutes to above itemized schedule and

Standard Schedule, Hours per 33-ft. Rail will be: 1.740.

Drawing a Second Line of Spikes:

If it is necessary to draw more than one line of spikes on one side, add ninety minutes to above itemized schedule and

Standard Schedule, Hours per 33-ft. Rail will be: 1.773.

Removing Anticreepers:

A standard time of .5 minute each will be allowed for removing anti-creepers from rail.

Making Connections:

Add to the standard hours computed for laying the rail additional hours for making connections as follows:

For each connection one per cent of the total actual hours on rail laying reported for the day.

EXAMPLE

A gang of twenty men laying 100 rails in a day, and making four connections, where detention is ten per cent:

100 x 1.623	162
Four connections at .01 of 200 hours	8
Total standard hours	170
Total actual hours working	180
Total detention	20

Performance—95 per cent.

The only detention allowed will be that authorized for the section where the rail is being laid.

Exhibit "C"

METHOD: CROSS-TIES—RENEWING

TRACK RAISED—STONE BALLAST

If ballast is dirty it must be cleaned before track is raised.

After the first raise is made and all ties tamped, the gang begins to renew ties. First, spikes are drawn and sufficient cribbing out done to permit ties to be moved sidewise in crib and drawn out. Bed is then prepared and new tie is inserted, using tie tongs. It is held up till tamped, after which spiking follows. The schedule includes piling for burning, using pyramidal piles parallel to track containing not more than 15 ties. These ties should not be burned under signal or telegraph wires.

Before beginning tie renewal the Foreman will go over the new ties marking (1) those ties to be used under joints, (2) which side of tie is to be uppermost and (3) a line indicating where the outside base of the outside rail should come.

One man should be assigned to draw spikes on all ties to be renewed. The remainder of the gang should work in pairs, except in large gangs where different men may be assigned to the different operations.

GRAVEL OR CINDER BALLAST

Ties should be marked by Foreman as explained under "Track Raised —Stone Ballast." First, spikes are drawn on ties to be renewed. Then, when the track is raised with jacks, the old ties are left in their bed and drawn out with picks. New ties are placed, and when jack men have moved forward, the new ties are tamped while being held up against the rail. Spiking follows. Men work in pairs. In large gangs, different men may be assigned to the different operations.

TRACK NOT RAISED—STONE BALLAST

Before renewals the Foreman should mark ties as explained in "Track Raised—Stone Ballast."

First, sufficient ballast should be removed to allow old tie to be readily moved sidewise in crib, then drawn out. The bed is then prepared and new tie drawn in with tie tongs, after which tie is held up to rail and tamped under both faces of the tie to outer end of tie and eighteen inches inside of rail. Spiking follows.

Ballast is cleaned if dirty and returned to crib and the shoulder dressed. Men should work in pairs.

GRAVEL OR CINDER BALLAST

Method is same as for Stone Ballast, except that tamping is completed for full length of tie, men working opposite to each other.

Exhibit "C-1"

SCHEDULES: CROSS-TIES—RENEWING

TRACK NOT RAISED

OPERATION No.	OPERATION.	TIME DISTRIBUTION. MINUTES PER TIE. CRIBS FULL.			
		Stone Ballast		Gravel or Cinder Ballast	
		In Single or Outside Track.	Inside Track or as Noted Below*.	Main Track.	Side Track.
1	Cribbing out	18	27	10	6
2	Drawing spikes	3	3	3	3
3	Removing old tie	2	4	2	1
4	Preparing new bed	3	3	2	1
5	Carrying tie to place	2	2	2	2
6	Placing new tie	2	4	2	2
7	Applying two tie plates	1	1	1	1
8	Driving four spikes	4	4	4	4
9	Tamping	13	14	8	6
10	Replacing and dressing ballast	10	14	3	2
11	Carrying old tie and piling for burning	2	2	2	2
	Foreman, one-tenth of above time	6	8	4	3
	Total minutes for one tie, cribs full	66	86	43	33
	Standard Schedule, Hours per Tie, Cribs Full	1.1	1.43	.72	.55
	Total minutes for one tie, cribs ¾ full.	59	74	40	30
	Standard Schedule, Hours per Tie, Cribs ¾ Full	1.0	1.23	.67	.50
	Total minutes for one tie, cribs ½ full.	53	63	36	26
	Standard Schedule, Hours per Tie, Cribs ½ Full	.9	1.05	.60	.43
	Total minutes for one tie, cribs ¼ full.	42	56.50	32	25
	Standard Schedule, Hours per Tie, Cribs ¼ Full	.7	.94	.53	.42
	If stone ballast is dirty, cribs and shoulders should be thoroughly cleaned, forking all the stone. In that case the total times and schedules would be as follows:				
	Total minutes for one tie, cribs full	79	99	....	....
	Standard Schedule, Hours per Tie, Cribs Full	1.32	1.65	....	....
	Total minutes for one tie, cribs ¾ full.	66	81	....	....
	Standard Schedule, Hours per Tie, Cribs ¾ Full	1.00	1.35	....	....
	Total minutes for one tie, cribs ½ full.	55	65	....	....
	Standard Schedule, Hours per Tie, Cribs ½ Full	.92	1.08	....	....

* Use this schedule when additional cribbing out is necessary by reason of the existence of three or more tracks on close centers at same level or where there is an obstruction such as platform or wall.

TRACK RAISED

OPERATION No.	OPERATION.	TIME DISTRIBUTION. MINUTES PER TIE. CRIBS ¾ FULL AFTER RAISE. Stone Ballast.	Gravel or Cinder Ballast.
1	Cribbing out	6	....
2	Drawing spikes	3	3
3	Removing old tie	1.5	1.5
4	Preparing new bed	2.5	2
5	Carrying tie to place	2	2
6	Placing new tie	2	2
7	Driving four spikes	4	4
8	Carrying old tie and piling for burning	2	2
	Foreman, one-tenth of above time	2	1.5
	Total minutes for one tie, cribs ¾ full	25	18
	Standard Schedule, Hours per Tie, Cribs ¾ Full	.42	.30
	Total minutes for one tie, cribs ½ full	21	17
	Standard Schedule, Hours per Tie, Cribs ½ Full	.35	.28
	Total minutes for one tie, cribs ¼ full	17	16
	Standard Schedule, Hours per Tie, Cribs ¼ Full	.28	.27

If tie places are applied the above schedules become:

WITH TIE PLATES

	Standard Schedule, Hours per Tie, Cribs ¾ Full	.44	.32
	Standard Schedule, Hours per Tie, Cribs ½ Full	.37	.30
	Standard Schedule, Hours per Tie, Cribs ¼ Full	.30	.29

Exhibit "D"

INSTRUCTIONS FOR REPORTING AND DISTRIBUTING TRACK WORK TIME CHARGES

SINGLE OPERATIONS

Kind of Work.	Manner of Reporting.	Items To Be Included.
Lining— (Acct. 220-e)	State feet of track lined and whether main or side track...	Breaking down shoulder, lining track, replacing and dressing ballast.
Surfacing— (Acct. 220-e)	State total number of ties tamped and feet of track surfaced, whether tamping one or both ends of ties, number of faces, condition of cribs, kind of ballast and if main or side track........................	Cribbing out, tamping, replacing and dressing ballast.
Gauging— (Acct. 220-e)	State number of ties gauged, whether with or without adzing, and if main or side track..	Pulling spikes, plugging holes, adzing and respiking to gauge.
Laying Rail— (Acct. 220-c)	State weight, amount laid in feet, whether new or repair and if laid in Main Track or Siding. State kind of joints on new and old rail, number of connections made; if any anti-creepers removed, state number. State time placing tie plates and numbers of plates. Make separate report of time distributing rail, new or repair and loading rail removed.........	Pulling spikes, lining out old rail, adzing, lining in new rail, putting on rail joints, full bolting, full spiking to gauge, uncoupling old rail, trucking material, flagmen and water boy. Time consumed removing old tie plates and placing new plates to be reported separately. Separate report to be made of time consumed unloading rail to be laid and loading rail removed.
Replacing Broken and Defective Rail— (Acct. 220-c)	State weight, number of rails and length, whether new or repair, and kind of joints used. Show time trucking and distance trucked, whether on hand or push car, and number of flagmen used.....................	Pulling spikes, lining out old rail, adzing, lining in rail, putting on rail joints, full bolting, full spiking to gauge and flagmen. If tie plates are changed make separate charge, also separate time consumed loading, unloading and trucking rail.
Replacing Rail Joints— (Acct. 220-d)	State number, kind of joint and number of holes..............	Removing old bolts and joint; placing new joint and full bolting.
Tightening and Replacing Bolts— (Tightening bolts Acct. 220-e. Replacing bolts Acct. 220-d)	State number of bolts tightened, number renewed and on which track.........................	Removing old bolts, putting in and tightening new bolts and tightening old bolts.
Renewing Cross-Ties— (Digging In) (Acct. 220-b)	State number of ties; with or without plates; kind of ballast; condition of cribs and whether main or side tracks. If trucking show number of ties, distance trucked, number of loads and number of flagmen used..........................	Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, tamping, refilling cribs, dressing ballast, carrying and piling old tie for burning, if less than 50 feet. If new tie is moved more than 100 feet or old tie is moved more than 50 feet, separate time consumed loading, unloading and trucking. If ballast is cleaned, the time consumed should be reported separately.

Exhibit "D"

SINGLE OPERATIONS—Continued

Kind of Work.	Manner of Reporting.	Items To Be Included.
Respacing Ties— (Acct. 220-b)	State number of ties, kind of ballast, condition of cribs and whether or not track is raised.	Cribbing out, driving tie to place, tamping, replacing and dressing ballast. If respacing is done during raise, a portion of cribbing out, the tamping, and a portion of replacing and dressing ballast, should be charged to "Surfacing."
Renewing Switch Ties— (Acct. 220-b)	State number, length, kind of ballast, condition of cribs, singly or in sets and on main or side track....................	Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, tamping, refilling cribs, dressing ballast, carrying and piling old tie for burning, if less than 50 feet. If new tie is moved more than 100 feet or old tie moved mcre than 50 feet, separate time consumed loading, unloading and trucking. If ballast is cleaned, the time consumed should be reported separately.
Replacing Frog— (Acct. 220-d)	State weight of rail, frog number and location. Show time trucking, distance trucked and number of flagmen used...........	Removing old frog and plates, placing new frog and plates, full spiking, and flagging. Separate time consumed loading, unloading and trucking.
Replacing Switch— (Acct. 220-d)	State weight of rail, length of points and location. Show time trucking, distance trucked, whether on hand or push car, and number of flagmen used....................	Removing old switch, placing and bolting new switch, adjusting and flagging. Separate time consumed loading, unloading and trucking.
Replacing Guard Rails— (Acct. 220-d)	State weight of rail, length of guard rail, number of clamps, whether plated or unplated, and location. Show time trucking, distance trucked, whether on hand or push car, and number of flagmen used.	Removing clamps, removing old guard rail, placing new guard rail, replacing clamps and flagging. Separate time consumed loading, unloading and trucking.
Replacing or Installing Guard Rail Clamps— (Acct. 220-d)	State whether replacing or installing, number of clamps and make. Show time trucking, distance trucked, whether on hand or push car, and number of flagmen used...............	Removing old clamps and placing new. If a large number of clamps are being replaced or installed, separate time consumed loading, unloading and trucking.
Applying Tie Plates— (Acct. 220-d)	State number of plates applied. Show number of plates, distance trucked, whether on hand or push car, and number of flagmen used...............	Pulling spikes, adzing, placing plates and spiking to gauge. Separate time consumed loading, unloading and trucking.
Applying Anti-Creepers— (Acct. 220-d)	State number and kind. Show number of anti-creepers, distance trucked, whether on hand or push car, and number of flagmen used...............	Moving ballast, applying anti-creeper and tightening. Separate time consumed loading, unloading and trucking.

Exhibit "D"

SINGLE OPERATIONS—Concluded

Kind of Work.	Manner of Reporting.	Items To Be Included.
Replacing Other Track Material not Specified Above— (Acct. 220-d)	State amount and kind. If trucking is done, show amount of material, distance trucked, whether on hand or push car, and number of flagmen used...	All operations required to remove old material and install new. Separate time consumed loading, unloading and trucking.
Cleaning Switches— (Acct. 202-b)	State number cleaned...........	Include time cleaning frog, switch and derail.
Cleaning Snow and Ice— (Acct. 272)	State number of switches cleaned. Make separate report of cleaning platforms..........	Include time cleaning frog, switch and derail.
Cleaning Weeds— (Acct. 202-b)	State number of feet cleaned and kind of ballast, and give location.........................	Removing weeds from ballast and scuffing shoulder.
Cleaning Right of Way— (Acct. 202-b)	State amount cleaned by feet of track and give location.......	Removing miscellaneous scrap, drift, dirt and other material from tracks and right of way.
Mowing— (Acct. 202-b)	State amount mowed by feet of track, number and width of swathes and give location.....	Cutting and disposing of brush, grass, weeds, etc.
Ditching— (Acct. 202-a)	State location, amount in feet and method. If wheelbarrow is used, state number of loads and distance wheeled. If ditching car is used, give same information.........................	Constructing or cleaning tile or open ditches. Include time placing and removing plank for trucking, laying and removing track for ditching cars, loading, trucking and unloading dirt. If steam ditcher is used special report to be made.
Patrolling— (Acct. 202-c)	State distance covered in miles..	When track walker is tightening bolts or doing other work while patrolling make separate charge.
Trucking— (Acct. 220)	State amount and kind of material, distance trucked, whether on hand or push car, and number of flagmen used.......	Loading, unloading, trucking and flagging. (Any material handled on hand, push or motor cars.)
Loading and Unloading— (Miscellaneous Material) (Acct. 220)	State amount and kind of material and kind of car, whether box, flat, gondola or hopper moving or standing...........	Unloading, carrying and piling material or carrying and loading material.
Wasting Slag and Refuse— (Acct. 202-g)	State kind of car, number of cars unloaded and location.........	Unloading and spreading slag and refuse. If tracks are thrown or raised in connection with unloading make separate distribution of time.
Cleaning Ballast— (Screens or Forks) (Acct. 202-b)	State number of cribs and depth; feet of shoulder width and depth; and feet of center ditch, giving depth and track centers.	Removing ballast from shoulder, cribs and center ditch, cleaning with forks or screens, replacing cleaned stone, dressing ballast and disposing of refuse.

Exhibit "D"

COMBINED OPERATIONS

Kind of Work.	Manner of Reporting.	Items To Be Included.
Ballasting— (Preparing roadbed and applying ballast, Acct. 220-a. Applying ties, Acct. 220-b)	Distribute time to the following items: Feet of track stripped, feet of roadbed prepared, number of ties renewed, number of ties respaced, feet of track ballasted, number of cars of ballast unloaded, feet of first raise, feet of second raise, feet lined, feet of track dressed and amount trucked. For details of reporting each separate item, see instruction for reporting that particular item...........	Stripping track: Digging out and disposing of old ballast from cribs, center ditch and shoulders. (If old ballast is used to build standard roadbed section, charge second handling to Preparing Roadbed.) Preparing Roadbed: Widening and preparing subgrade to receive ballast. Renewing Ties: Carrying new tie if less than 100 feet, removing old tie, carrying 50 feet and piling for burning, placing new tie, placing plates, spiking to gauge, temporary surface and flagging. Respacing: Cracking up spikes, driving ties to place and driving down spikes. Unloading Ballast: Releasing ballast cars. First Raise: Jacking up track 4" to 6" tamping and flagging. Second Raise: Jacking up track 4" to 6" tamping to final surface and flagging. Lining: Throwing to standard centers and detail lining. Dressing: Dressing center ditch and shoulders to standard section.
Surface and Raise Out of Face and Renew Ties— (Applying ties, Acct. 220-b. Surfacing track, Acct. 220-e)	State number of ties renewed, number of ties respaced, feet of track surfaced, feet of track lined and feet of track dressed. If ties are trucked state number and distance trucked...... If runoff at end of day's work is tamped as solidly as other track raised, one half of it may be included in "Feet of Track Surfaced." For details of reporting each separate item, see instructions for reporting that particular item...............	Renewing ties: Carrying new tie if less than 100 feet, cribbing out, removing plates, removing old tie, placing new tie, replacing plates, carrying and piling old tie for burning, if less than 50 feet. Respacing: Driving tie to place. Surfacing: Cribbing, jacking up track, tamping and flagging. Lining: Breaking down shoulder, lining track, replacing and dressing ballast. Dressing Ballast: Unloading ballast to refill cribs, dressing cribs, shoulder and centre ditch.

Separate distribution of time must be made for any items of work not covered by the above list.

Time charges for one item must not run over into the charge for another item. For instance, in surfacing, if there is any lining or gauging, a careful separation must be made to each class of work and not lumped as surfacing.

The time consumed loading, unloading and trucking material is in all cases included in the cost of applying the material, but a separate distribution of the time consumed on this work must be made.

The time flagging must in all cases be charged to the work being protected.

Exhibit "D"

REPORTING "OTHER DEPARTMENT" WORK

In order that the time spent on work for other departments may be properly separated from the time spent on the various items of maintenance work the following list of charges to "Conducting Transportation" and "Motive Power" is given as a guide:

Conducting Transportation

Cleaning stations.
Cleaning towers.
Cleaning cinders from tracks at designated points.
Cleaning refuse from cars.
Handling coal at tipples.
Handling coal at water stations.
Handling coal at stations and towers.
Handling coal for engines.
Lighting switches and station lamps.
Throwing switches.
Renewing batteries—Interlockers.
Renewing batteries—Semi-automatic signals.
Renewing batteries—Automatic signals.
Feeding and watering stock.
Burying stock.
Pumping water.
Hauling water.
Handling engine sand.
Wrecking.
Transferring freight.
Handling baggage.
Handling U. S. mail.
Assisting hostler.
Handling stoves, furniture and station supplies.
Handling ice.
Watching crossings.
Repairs to outside property account accidents.
Recharging fire extinguishers.
Draw bridge operation.
Floating equipment operation.
Unloading slag—wasting.

Motive Power

Repairs to freight cars.
Repairs to passenger cars.
Repairs to floating equipment.
Repairs to work equipment.

The items of work listed above must be scheduled by the Supervisor when possible and when so scheduled will be posted on Daily Record Sheet (Exhibit G) under Supervisor's Schedules and the detail shown on a supplementary statement accompanying the monthly report. Likewise items of "Ungraded Work" will be posted as provided for in instructions.

Any items of work contained in the above list which are not scheduled by the Supervisor and which are not classed as "Ungraded Work" will be posted on Daily Record Sheet (Exhibit G) under "Unscheduled Other Departments" and graded at 67 per cent.

Miscellaneous work which is not covered by a standard schedule will be scheduled by the supervisor as follows:

The supervisor from his experience will estimate conservatively the time which would be required to do the work under ordinary conditions. This estimate will represent an average performance of 67 per cent efficiency from which the standard hours representing 100 per cent efficiency will be computed by taking 67 per cent of the supervisor's estimate and shown on the dispatch.

On the Monthly Record of Track Work Efficiency (Exhibit "H"), there is a column headed "Total Payroll Hours," the total of which must check with the totals shown on the payrolls. This is not possible if any time is omitted; therefore, all work of whatever nature performed by track men must be recorded. All work not scheduled will be posted in a column headed "Ungraded Work," entering the actual hours only; no standard hours or percentage will be shown.

EXHIBIT "E"

NORTH & SOUTH RAILROAD CO.

MAINTENANCE OF WAY DEPARTMENT

SECTION PLANNING SHEET

DIVISION.............................. SUB DIVISION No.........SECTION No..........FOREMAN.............................. MONTH OF.................... 192.....

Mile Posts		E.B.	W.B.	E.B.	W.B.	E.B.	W.B.	E.B.	W.B.	E.B.	W.B.	E.B.	W.B.	E.B.	W.B.
TIE RENEWALS		Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted	Ties Spotted
		Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month	Renewals Compl'd to First of Month
		Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month	Planned for Month
	W.B.														
	E.B.														
Laying Rail	W.B.														
	E.B.														
Ballast-ing	W.B.														
	E.B.														
Cleaning Ballast	W.B.														
	E.B.														
Surfacing out of face	W.B.														
	E.B.														
Ditching	W.B.														
	E.B.														
	W.B.														
	E.B.														
	W.B.														
	E.B.														

Note - This form to be filled out monthly by the Division Engineer and Supervisor for each Section. From this the Supervisor will dispatch the work to each Foreman.—

SEASONS WORK = Yellow PLANNED FOR MONTH = Red WORK COMPLETED = Green

1 Deduct detention at end of pay period only, on line provided at bottom
2 Fill in total detention at end of pay period only, in detention column
3 No detention to be deducted from Patrolling Unscheduled O.O. and Unscheduled M of W Miscellaneous
4 Total Working Hours to be filled in at bottom of column at end of pay period only, and performance calculated and recorded
5 Standard Hours for total Unscheduled O.O. and total Unscheduled M of W Miscellaneous to be recorded at bottom of respective columns at end of pay period only

FOREMAN ....

NORTH & SOUTH RAILROAD CO.

MAINTENANCE OF WAY DEPARTMENT

DAILY RECORD TRACK WORK PERFORMANCE

SECTION DETENTION ALLOWANCE .%

SECTION No..

EXHIBIT "G"

MONTH OF ....192..

	DATE	DETAIL OF SCHEDULED WORK (including Standard A F E and Supervisors Schedules)																																														TOTAL SCHEDULED HOURS		DETAIL OF UNSCHEDULED O.O. WORK						TOTAL UNSCHEDULED OTHER DEPT HOURS		DETAIL OF UNSCHEDULED M. OF W. MISCELLANEOUS WORK										TOTAL UNSCHEDULED M of W MISC HOURS		TOTAL WORKING HOURS			DETENTION		UNGRADED		TOTAL PAY ROLL HOURS	DISPATCHED HOURS	DATE	REMARKS
		LINING		SURFACING		GAUGING		RENEWING CROSS TIES		RENEWING SWITCH TIMBERS		RESPACING TIES		RENEWING RAIL		CLEANING BALLAST		DRESSING BALLAST		UNLOADING BALLAST		APPLYING OTHER TRACK MATERIAL		LOADING OR UNLOADING RAIL		LOADING OR UNLOADING TIES		HANDLING MATERIAL		TIGHTENING BOLTS																																												TRAIN TRAVEL	OTHER	PATROLLING	OTHER				
		ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC.	ST	AC.	ST	AC.	ST	AC	ST.	AC.	ST	AC	ST	AC	ST	AC	ST	AC	ST	AC	ST.	AC	%								
																																																																												1	
																																																																														2	
																																																																														31	
																																																																														Total	
																																																																														Detention	
																																																																															Total 2nd Half	
																																																																															Monthly Total	

. DIVISION

SUB-DIVISION NO ....

SUPERVISOR ....

ASST SUPERVISOR ....

NORTH & SOUTH RAILROAD CO.

MAINTENANCE OF WAY DEPARTMENT

MONTHLY RECORD TRACK WORK EFFICIENCY

PERCENT OF WORKING HOURS SCHEDULED

PERCENT OF TOTAL HOURS DISPATCHED............

EXHIBIT "H"

SHEET No.

MONTH OF ....192..

	1 SECT No	2 LINING			3 SURFACING			4 GAUGING			5 RENEWING CROSS TIES			6 RENEWING SWITCH TIES			7 RESPACING TIES			8 RENEWING RAIL			9 CLEANING BALLAST			10 DRESSING BALLAST			11 APPLYING OTHER TRACK MATERIAL			12 HANDLING MATERIAL			13 TIGHTENING BOLTS			14			15			16			17 SCHEDULED FORM A F E			18 SCHEDULED OTHER DEPARTMENTS			19 MISC SUPERVISORS SCHEDULES			20 TOTAL SCHEDULED HRS			21 UNSCHEDULED M of W MISCELLANEOUS			22 UNSCHEDULED FORM A.F.E.			23 UNSCHEDULED OTHER DEPARTM'S			24 TOTAL WORK'G HRS (EXCEPT UNGRADED)			25 DETENTION		26 TOTAL BONUS HOURS	27 UNGRADED		28 TOTAL PAYROLL HOURS	29 SECT No.	30 FOREMAN AND HEADQUARTERS
		STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	STAND HRS	ACTUAL HRS	%	TRAIN TRAVEL	OTHER		PATROL LINE	OTHER			

NORTH & SOUTH RAILROAD CO.

MAINTENANCE OF WAY DEPARTMENT

EXHIBIT "I"

SUB-DIVISION No........

RECORD OF TRACK AND ROADBED FEATURES

..................................SUPERVISOR

..................................ASST. SUPERVISOR

SECTION NUMBER	M.P. To M.P.		LENGTH MILES	MAIN TRACK-MILES					MILES OF SIDING					SWITCHES MAIN TRACK				CROSSING MAIN TRACK BR OR SIDE						TRACK PANS 100%-½ MILE	BLDGS & GROUNDS 12%-8	BRIDGE APP. 5%-20	DITCHES 25%-4 MILES	TUNNELS	ARBITRARY	EQUIVALENT MILEAGE	JANUARY		FEBRUARY		MARCH etc.		JAN.	FEB.	MAR etc.	FORCE ALLOTMENT						REMARKS
				FIRST 100% 1	SECOND 37%-1.15	THIRD 75%-1.33	MAIN BR 50%	TOTAL	PASSING 50%-2	LEAD TRACKS 50%-2	OTHER SIDG & YARD TRACKS 25%-4	INDUSTRIAL 30%-3.33	TOTAL	HAND 8%-12	INTERLOCKED 11%-9	OTHER SW 5%-20	TOTAL	R.R. OR EL. 10%-10	CITY ST. 12%-8	COUNTRY RD. 4%-25	R.R. OF EL. 6%-16	CITY ST. 8%-12	COUNTRY RD. 2%-50								CONDITION PER CENT	EQUATED MILEAGE	CONDITION PER CENT	EQUATED MILEAGE	CONDITION PER CENT	EQUATED MILEAGE	FORCE REQUIRED	FORCE REQUIRED	FORCE REQUIRED	JANUARY	FEBRUARY	MARCH etc.				

NORTH & SOUTH RAILROAD CO.

MAINTENANCE OF WAY DEPARTMENT

EXHIBIT "J"

DIVISION .... SUB-DIVISION No........

TRACK CONDITION SHEET

MONTH .... 192....

	RELATIVE VALUE	SECTION NUMBER												SECTION - NUMBER										REMARKS
		C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	C	V	
ROADBED (Cuts and Fills, Berme, Slopes & Ditches)	5																							
TIES (Cross Ties and Switch Timber.)	14																							
BALLAST (Applying and Cleaning)	15																							
RAIL AND OTHER TRACK MATERIAL (Handling, Applying & Repairing)	12																							
LINE, SURFAC AND GAUGE	50																							
RIGHT OF WAY GROUNDS (Cleaning and Mowing)	4																							
TOTAL VALUE																								
EQUIVALENT MILEAGE																								
EQUATED MILEAGE																								

Note:-C = Condition Percent –
V = Calculated Value –

Relative value equivalent to ratio of time spent on each of above items of changing conditions to whole time spent on all such items.–
Condition Percent determined by monthly inspection.–
Note:–Patrolling and Miscellaneous Work having constant values are not considered in pro-rating values for changing track conditions.–

Exhibit "F"

WORK ORDER

Section No..................

OUTLINE OF WORK	Location of Work			Time to be Consumed
	Track	From	To	

Order No.....................

....19......

....Supervisor

	Hour	Date
Work Started	....	....................19......
Work Finished	....	....................19......

....Foreman

REPORT OF COMMITTEE VII—WOODEN BRIDGES AND TRESTLES

W. H. HOYT, *Chairman;*
H. AUSTILL,
O. C. BADGER,
C. H. BLACKMAN,
H. J. HANSEN,
W. E. HAWLEY,
H. T. HAZEN,
C. S. HERITAGE,
A. O. RIDGWAY, *Vice-Chairman;*
E. M. LEWIS,
J. B. MADDOCK,
D. W. SMITH,
L. L. SPARROW,
G. C. TUTHILL,
A. M. VANAUKEN,
S. L. WONSON,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully reports on the following subjects:

(1) Revision of the Manual

In Appendix A are given the changes and addition to the section of the Manual assigned to this Committee. This report is brief because of the intensive work done by this Committee last year in anticipation of the publication of the new Manual.

(2) Wooden Trestles—Open-Deck, Multiple-Story and Ballast-Deck

In Appendix B—Exhibits 1, 2, 3, 4, 5, 6, the Committee reports on subject No. 2, which has been before this Committee for two years for investigation and study. The Committee's recommendations are given under the heading of Conclusions.

(3) Fireproofing Wooden Bridges and Trestles

In Appendix C the Committee submits report on subject No. 3 and its recommendations are given under the heading of Conclusions.

CONCLUSIONS

1. The Committee recommends that the changes and additions to the Manual as given in Appendix A be approved.

2. The Committee recommends that the plans for standard Open-Deck Pile Trestles, Light Design, as shown in Appendix B, Exhibit 1, be approved for printing in the Manual as recommended practice.

3. The Committee recommends that the plans for standard Open-Deck Pile Trestles, Heavy Design, as shown in Appendix B, Exhibit 2, be approved for printing in the Manual as recommended practice.

4. The Committee recommends that the plans for standard Open-Deck Frame Trestle, Light Design, as shown in Appendix B, Exhibit 3, be approved for printing in the Manual as recommended practice.

5. The Committee recommends that the plans for standard Open-Deck Frame Trestle, Heavy Design, as shown in Appendix B, Exhibit 4, be approved for printing in the Manual as recommended practice.

6. The Committee recommends that the plans for standard Multiple-Story Trestles, as shown in Appendix B, Exhibit 5, be approved for printing in the Manual as recommended practice.

7. The Committee recommends that the plans for standard Ballast-Deck Trestles, as shown in Appendix B, Exhibit 6, be approved for printing in the Manual as recommended practice.

8. The Committee recommends that the recommendations as good practice in the report of the Sub-Committee on fireproofing wooden bridges and trestles, as given in Appendix C, be approved for printing in the Manual.

9. The Committee recommends that the outline of work for the ensuing year be received as information for the use of the Committee on Outline of Work.

10. The Committee submits in Appendix B, Exhibits 7, 8, abstracts of data and questionnaires, as information.

Outline of Work for Next Year's Study and Report

A. O. Ridgway, *Chairman;* W. H. Hoyt, A. M. Van Auken, C. S. Heritage, H. Austill, *Sub-Committee.*

1. Report on classification and grading rules for hardwood timber and lumber for railroad purposes.

2. Study and report on the useful strength of new, old and treated timber when used in railroad trestles, including a critical examination of the present theories of stresses when applied to timber under railroad load conditions.

3. Study and report on proper organization of Bridge and Building Departments.

4. Study and report on system of trestle inspection and reports covering the same.

Respectfully submitted,

The Committee on Wooden Bridges and Trestles,

W. H. Hoyt, *Chairman.*

Appendix A

(1) REVISION OF MANUAL

A. O. Ridgway, *Chairman;* H. T. Hazen, D. W. Smith, *Sub-Committee.*

Your Committee recommends the following changes in the Definitions, now in the Manual:

Present Form	*Proposed Form*
Cap—The horizontal member upon the top of piles or posts, connecting them in the form of a bent.	Cap—A horizontal member on the top of piles or posts, connecting them to form a bent.
Straight—Having a straight line of an axis.	Straight—Having a right line axis.

Add the following definition:

Ballast Curb—A longitudinal timber placed along the outer edge of the floor on ballast deck bridges to retain the ballast.

Appendix B

(2) STANDARD PLANS FOR WOODEN TRESTLES

By the Committee

Your Committee has had this subject under investigation and study during the two past years, having presented a progress report at the last convention. The Committee early this year issued a questionnaire on prevailing practice of railroads in design and use of wooden trestles, including details of multiple-story and ballast-deck trestles. The Committee carried on a voluminous correspondence with various authorities and encouraged engineering magazine discussion of some of its problems.

The Committee early in its studies realized that whatever plans it might present would be compromises of many viewpoints and would not therefore meet the complete approval of every engineer. Many good arguments may be advanced for plans and details other than those offered by the Committee. The Committee, however, has endeavored to recommend what in its judgment would make a consistent, conservative, safe and economical design. There will doubtless be some who would build lighter and others who would build heavier structures. In presenting four plans, using 12- and 16-ft. spans for light and heavy loading, the Committee feels that it has provided in a reasonable way for all railroad service trestles, except the temporary logging road, and heaviest railroad service where steel or concrete should be given serious consideration. The two spans provide for trestles in districts where the timber runs small and for districts where splendid heavy timber is available.

The Committee realizes that unlike many other forms of railroad material and structures where new material is being ordered every year, timber trestles are in most cases already installed and each railroad already has its own standards which will vary from the Committee's plans. Furthermore, many railroads have already large stocks of sizes of timber suitable for their own standards of construction. Therefore, these proposed standards will only be of value for comparison with present structures when either changes in existing standards are suggested or new railroad trestles are being planned. These plans, unless adopted by each railroad, will not affect materially the present demands on the timber supplies of the country. On the other side, if by chance these plans should supplant those already in use by the railroads, the variety of span and loading offered will give opportunity for the economical use of existing supplies of timber.

The Committee would therefore receive criticism in the spirit that there are many viewpoints in the design of these structures, but that it had after due investigation and study submitted these plans as its best judgment and maintains its support on these grounds.

The Committee spent a large amount of time and thought on the length of spans to be recommended. In last year's progress report it suggested a twelve-foot span. After careful consideration of the advantages of a sixteen-foot span, where flood conditions exist and in zones where Western fir can be readily secured, it decided to include both spans.

The Committee feels that there is a definite field of utility for a short and a long span, each serving better than a compromise one-span length between the two lengths recommended.

The Committee carefully considered the loadings and decided to keep in harmony with those of the steel specifications, which are Cooper's E-60 and a load which shall not be in any case lighter than three-fourths of the above. The Committee believes that for any structures designed to carry more than E-60, steel and concrete will be given serious consideration.

The Committee kept in mind also that freight cars and their loads have kept increasing until now they often exceed in intensity of loading many of the earlier locomotives. They would, therefore, recommend that great care in the choice between these two standard designs be used in order that the lighter design be not chosen for lines where heavy foreign cars are liable to be hauled over the line even though the lighter trestle might be sufficiently heavy for the motive power used.

In the choice of stringers the Committee desired to use a size which can be converted from the lighter design to the heavier design by the addition of another stringer of the same size to each chord of the span. It, therefore, decided on using three lines for the lighter loading and four lines for the heavier loading.

The question of design stresses was carefully investigated and studied. Without holding too closely to fixed stresses, the Committee wished to be consistent in the choice of design stresses for all four designs and has, therefore, not exceeded 1481 lb. per square inch in extreme fiber in bending, 221 lb. per square inch in end compression between the cap and stringer. The stresses have been investigated on the basis of possible actual sizes, the minimum sizes permitted by the specifications of A. R. E. A., rather than the nominal sizes.

Weight of timber and hardware were taken as 4.5 lb. per ft. B.M. Weight of rails and fastenings were taken as 150 lb. per lin. ft. of deck.

Horizontal shear was studied and the Committee is satisfied that its designs are in conformity with the best experience and present practice. The Committee has investigated the status of theory of horizontal shear and has decided that it is premature to advance any theory in support of its choice of stresses.

The Committee made some inquiry relative to the future supply of timber for bridge work and found that like many other problems there is a wide variance of judgment as to the future supply. Statistics and past history of the lumber industry indicate a diminishing and limited supply. Engineers in the lumber industry indicate that better methods of selection and cutting will prolong the time in which bridge material may be secured. The Committee believes that conservation of our present supply is necessary and therefore that the use of a 7 in. by 16 in. stringer which can be cut from the smaller timber is a measure of conservation in that it increases the number of trees which can supply stringer material.

Eight in. by 8 in. ties are shown because their use was indicated by more designs submitted than all other sizes put together. Ten-foot length was chosen because while in the number of designs the nine and ten-foot length were nearly equal, many more were using longer lengths of 11, 12, 13, and 14 feet than those using shorter lengths of 8 and 8½ feet. The ten-foot tie is also a better tie to use for the four-stringer chord.

Ties fastened every third tie appeared to be in more common use than other spacings and was deemed ample. Drift bolts were indicated in plans recommended in 1918 for fastening the ties to the stringers and were adopted by this Committee because of the maintenance required on bolts if used.

Five in. by 8 in. guard timbers were used because a six inch timber would encroach on the clearance diagram. The use of lag screws to fasten guard timber to ties is in accordance with previous A.R.E.A. recommendations.

The use of separator blocks of either metal or wood between the ties is recommended as worthy of further investigation and study.

Drift bolts are shown for fastening stringers to caps because this method is used by railroads as indicated by replies to questionnaire almost twice as often as all other methods put together. The Committee recommends that only one drift bolt be used in an intersection of chord with cap, feeling that one is sufficient and that more only increased the chance for decay and difficulty of realignment if necessary.

The Committee recommends four-pile bent for the light 12-foot span, five-pile bent for the heavy 12-foot span, five-pile bent for the light 16-foot span and six-pile bent for the heavy 16-foot span, and that the same number of posts be used in timber bents as for the corresponding spans and loadings of the pile bent designs. This gives a consistent series considering the loading and spans without excessive pile loading. All but the center one or two piles are shown driven on a batter to give greater stiffness to the bent.

Elevation on curves is best secured by cut-offs of posts or piles rather than by shims or tapered ties.

Three in. by 10 in. sway bracing is used as shown in returns almost in ratio of 3 to 1 of all other sizes together.

The 12 in. by 14 in. cap is used in more plans than all other sizes put together, and was used by the Committee for the lighter loading, but the Committee felt that under the heavier loading the 14 in. by 14 in. cap was to be preferred to give greater end bearing areas.

Where concrete footings may be used, the Committee has shown a design with the posts butting or resting directly on the concrete, thereby eliminating the sill. It usually early shows weakness by decay and compression. Horizontal braces above the concrete tie the posts together and dowels are used to hold the bent in line on the concrete and to aid the transfer of longitudinal stresses of the trestle to the foundation.

Concrete foundations under frame bents may be made as shown on drawings or as solid piers, depending on the cost of each.

The Committee recommends that where long round timber can be secured that it is good practice to use as long posts as possible to avoid multiple-story bents leaving out the horizontal sills.

Longitudinal horizontal girts are shown 6 in. by 10 in. because it is desirable that a stiff strut with ample bolting area be used. The Committee submitted the plan of lapping the girts by on the posts with double through bolting and dapping over the sash brace on the bent because in their judgment all forms of end to end arrangements of girts did not leave enough material to make secure the bolt fastenings and because of shrinkage of material it is difficult to keep the end contact tight, which is necessary if the brace is to be effective.

Longitudinal diagonal bracing are shown 3 in. by 10 in., as this size seems to be used by more roads than all those using other sizes put together.

There were many different layouts of longitudinal diagonal bracing indicated in replies to questionnaire, but the Committee recommended the bracing in every third panel for pile bents and in every other panel for frame bents as being sufficient in ordinary circumstances. High trestles require more and are indicated in the plan for multiple story trestles.

In constructing bulkhead at the ends of wooden trestles the Committee recommends as good practice the use of sections of old rail as separators between piles or posts and end planking.

The Committee in presenting plans for ballast deck timber trestles has not had as much material information from railroads' experience because this type of deck is more recent in its development and has not been as extensively used as the open deck. The Committee, therefore, presents a compromise of the best features.

The Committee felt that experience indicates that the open system of stringers with plank covering was the better type because of convenience of repair, less tendency to decay and the economical use of stringer material.

The Committee chose the single span length stringer lapping by on the caps the full width of cap because this plan enables the use of shorter timbers, the removal and repair of one panel at a time, and where creosoted timber is used, the avoidance of cutting the stringers after treatment.

The stringers are shown laid skew, which arrangement develops a more symmetrical loading of the stringer at the center of the span.

With the stringers held in place by planks spiked to them, it was decided that four drift bolts would be sufficient at each bent to hold deck to caps.

In the replies returned to questionnaire there were as many 14-foot decks as all other widths put together and the Committee therefore chose the 14-foot width.

There was no great predominance of any one span length but 13 ft. and 13 ft. 6 in. represented five out of fifteen plans, 14 ft., 14 ft. 6 in., and 15 ft. represented six out of fifteen plans but the Committee did not want to use larger than 8 in. by 16 in. stringers nor stresses higher than the value given below. Eight in. by 16 in. stringers with E-60 loading on deck have a calculated fiber stress of 1,470 lb. per square inch of possible actual size.

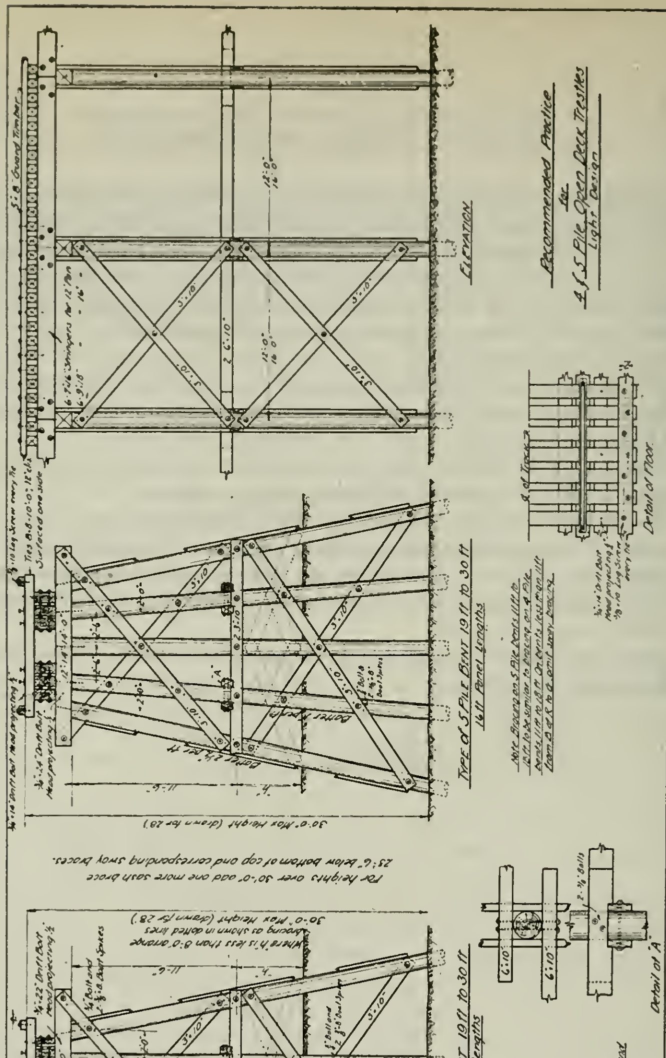
The Committee decided on six piles or posts to the bent because of the increased dead load carried and the natural greater permanence of this type of structure.

The use of 12 in. by 14 in. caps exceeded in number all other sizes together, as did also the use of 16-foot length caps.

The ballast curb was chosen 8 in. wide because the use of this width exceeded all other widths put together, while the Committee chose 8 in. for height in face of the fact that the larger number of plans showed only 6 in. high because the ballast should be retained better than would be done by a 6 in. curb.

Four-inch planking was thought would give a better distribution of loading over the stringers.

Exhibit 1



Recommended Practice for 4 & 5 Pile Open Deck Trestles
Light Design
Elevation
5"x8" Guard Timber
Type of 5 Pile Bent 19 ft to 30 ft
16 ft Panel Lengths
30'-0" Max Height (drawn for 28')
For heights over 30'-0" add one more sash brace 25'-6" below bottom of cap and corresponding sway braces.
Type of 4 Pile Bent 19 ft to 30 ft
12 ft Panel Lengths
18'-0" Max Height
Type of 4 Pile Bents 11 ft to 18 ft
12 ft Panel Lengths
Detail of Floor
Detail of "A"
Diagram showing Longitudinal Bracing

Exhibit 2

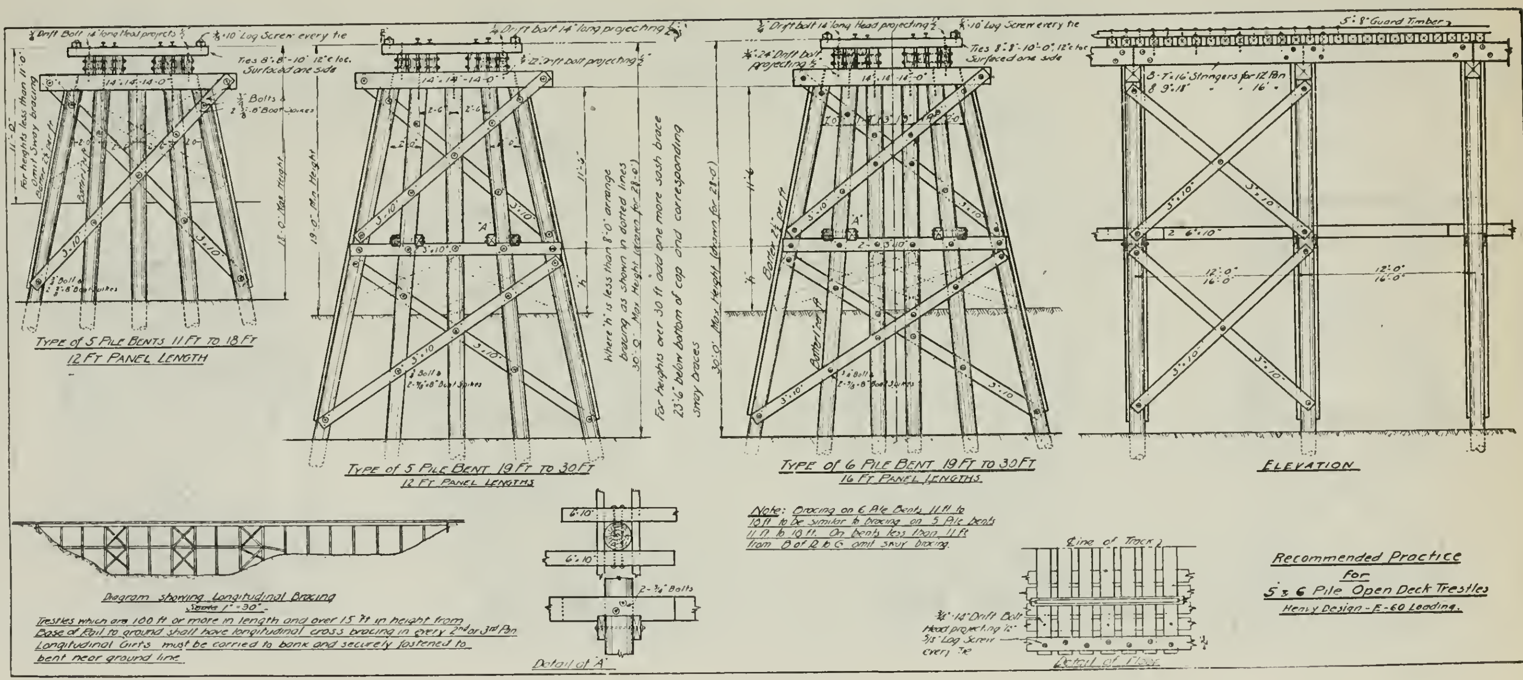
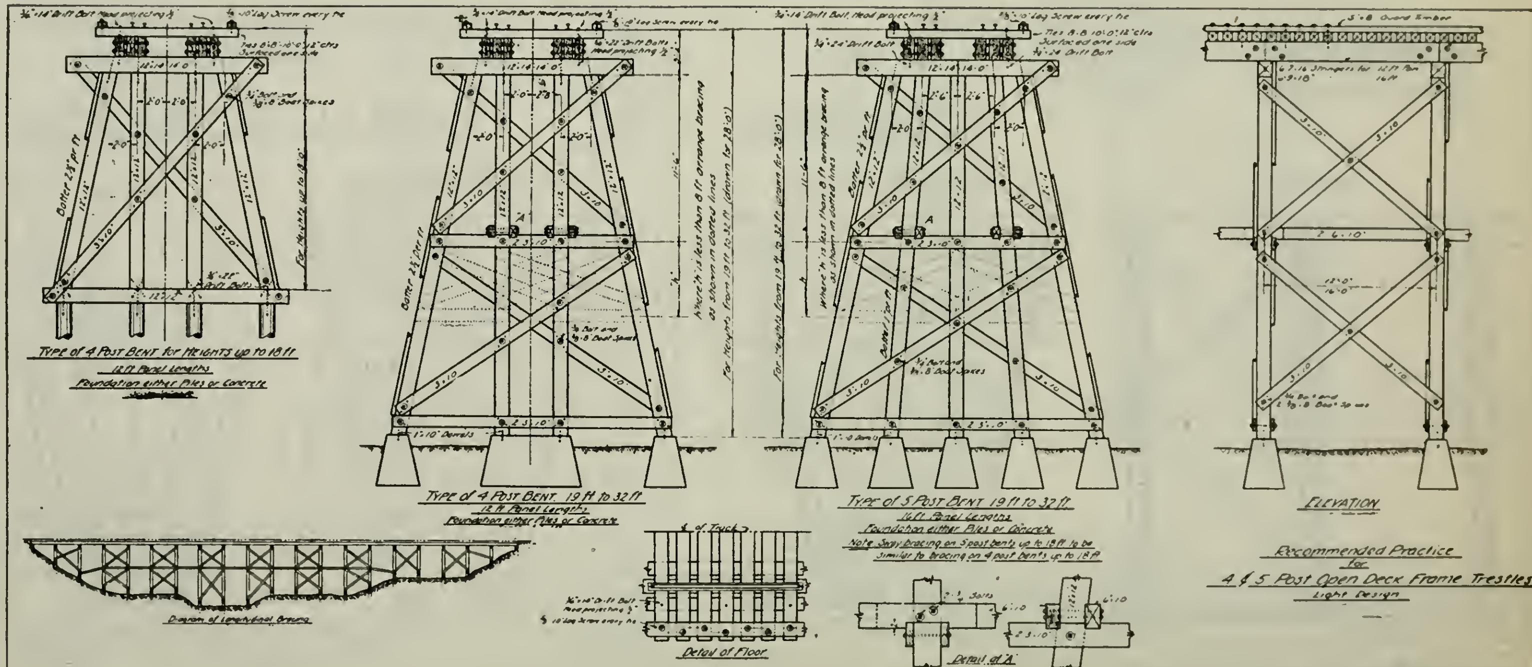
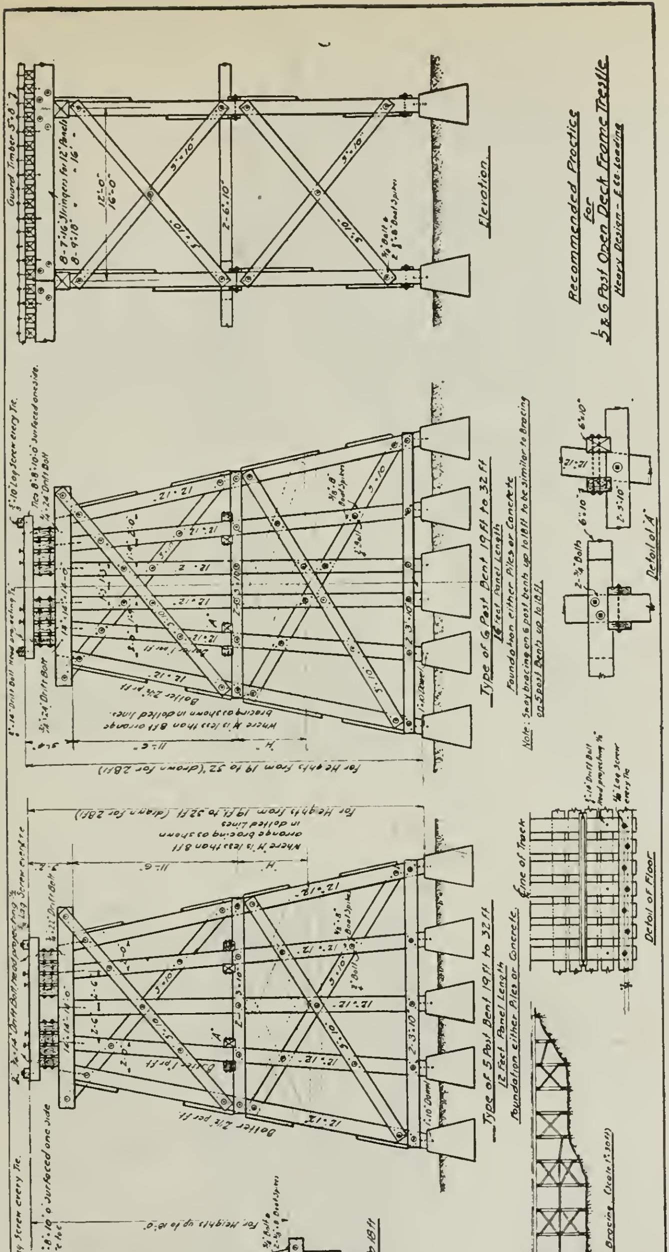

TYPE of 5 PILE BENTS 11 FT TO 18 FT
12 FT PANEL LENGTH
TYPE of 5 PILE BENT 19 FT TO 30 FT
12 FT PANEL LENGTHS
TYPE of 6 PILE BENT 19 FT TO 30 FT
16 FT PANEL LENGTHS
ELEVATION
Where 'h' is less than 8'-0" arrange bracing as shown in dotted lines
For heights over 30 ft add one more sash brace 23'-6" below bottom of cap and corresponding sway braces
Note: Bracing on 6 Pile Bents 11 ft to 19 ft to be similar to bracing on 5 Pile bents 11 ft to 18 ft. On bents less than 11 ft from B of R to G omit sway bracing.
Diagram showing Longitudinal Bracing
Trestles which are 100 ft or more in length and over 15 ft in height from Base of Rail to ground shall have longitudinal cross bracing in every 2nd or 3rd Pan. Longitudinal Girts must be carried to bank and securely fastened to bent near ground line.
Detail of 'A'
Detail of Floor
Recommended Practice
For
5 & 6 Pile Open Deck Trestles
Heavy Design - E-60 Loading.

Exhibit 3



TYPE OF 4 POST BENT FOR HEIGHTS UP TO 18 FT
12 Ft Panel Lengths
Foundation either Piles or Concrete
TYPE OF 4 POST BENT 19 Ft to 32 Ft
12 Ft Panel Lengths
Foundation either Piles or Concrete
TYPE OF 5 POST BENT 19 Ft to 32 Ft
16 Ft Panel Lengths
Foundation either Piles or Concrete
Note: Sway bracing on 5 post bents up to 18 ft to be similar to bracing on 4 post bents up to 18 ft
ELEVATION
Recommended Practice for 4 & 5 Post Open Deck Frame Trestles
Light Design
Diagram of Longitudinal Bracing
Detail of Floor
Detail at 'A'
Where 'h' is less than 8 ft arrange bracing as shown in dotted lines
For Heights from 19 ft to 32 ft (drawn for 28'-0")
For Heights up to 18'-0"
Batter 2 1/2" per ft

Exhibit 4



Recommended Practice for 5 & 6 Post Open Deck Frame Trestle
Heavy Design - E 60 Loading
Elevation
Type of 6 Post Bent 19 ft to 32 ft
16 feet Panel Length
Foundation either Piles or Concrete
Detail of "A"
Type of 5 Post Bent 19 ft to 32 ft
12 feet Panel Length
Foundation either Piles or Concrete
Detail of Floor
Type of 5 Post Bent for Heights up to 18 ft
12 feet Panel Length
Foundation either Piles or Concrete
Diagram of Longitudinal Bracing

Exhibit 5

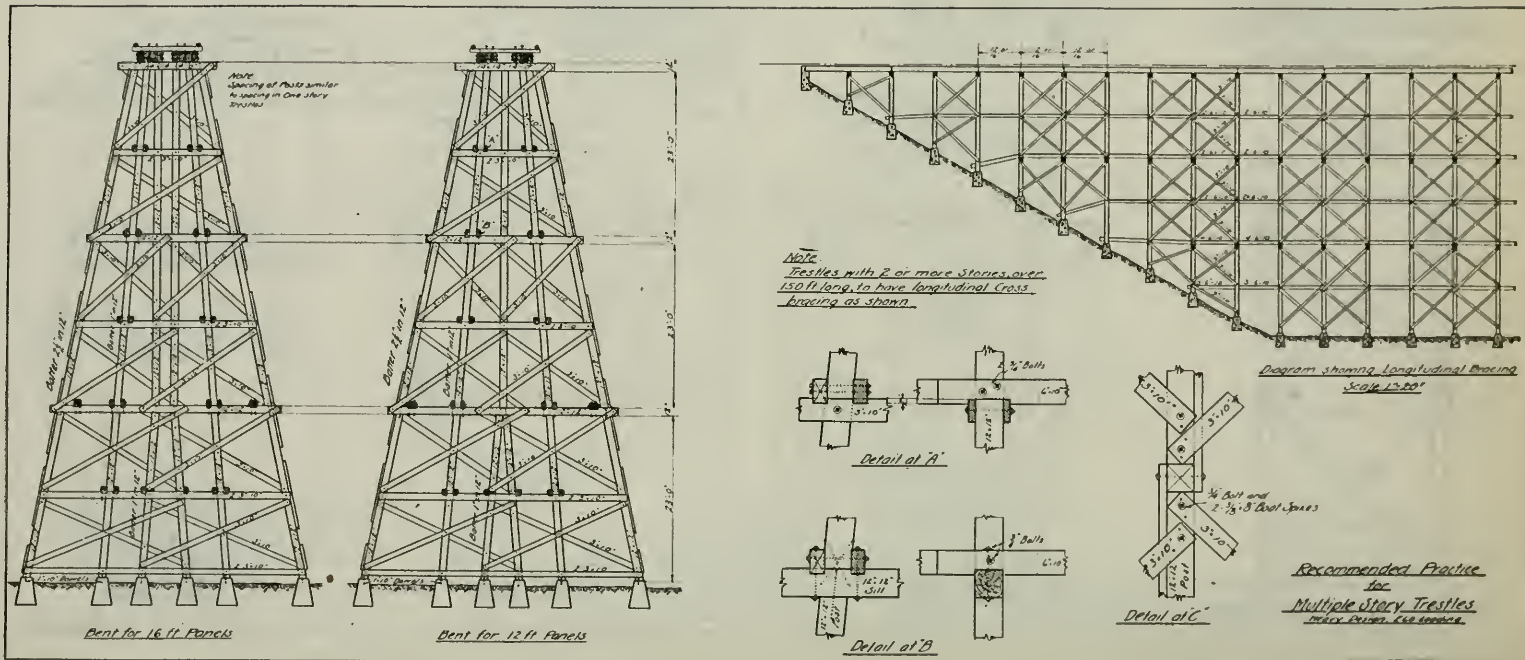
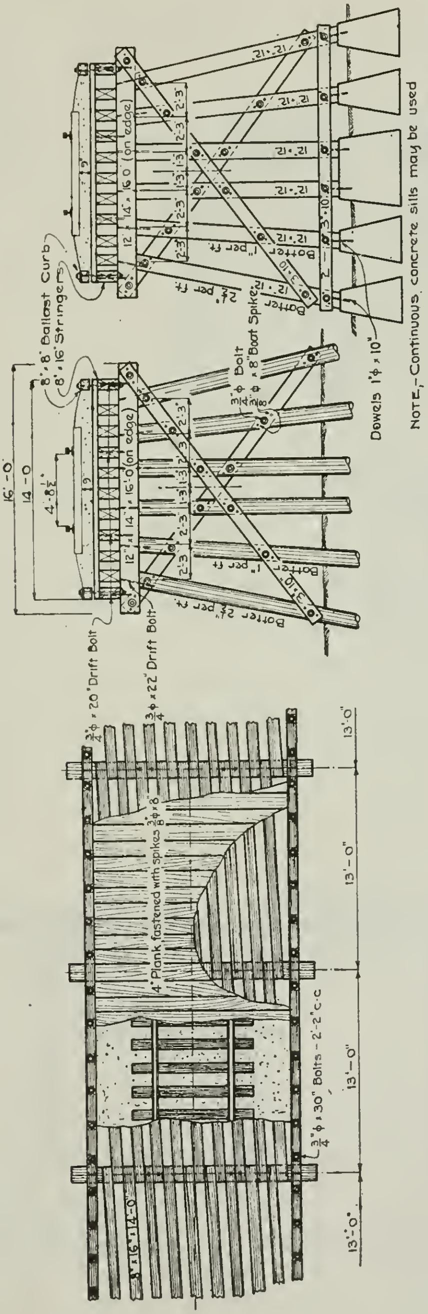

Note
Spacing of Posts similar to spacing in One story Trestles
Batter 2¼" in 12"
23'-0"
Bent for 16 ft Panels
Bent for 12 ft Panels
Note.
Trestles with 2 or more Stories over 150 ft long, to have longitudinal Cross bracing as shown.
Diagram showing Longitudinal Bracing
Scale 1"=20'
Detail at "A"
Detail at "B"
Detail at "C"
¾" Bolt and 2-⅓" 8" Boat Spikes
12"x12" Post
12"x12" Sill
Recommended Practice
for
Multiple Story Trestles

Exhibit 6

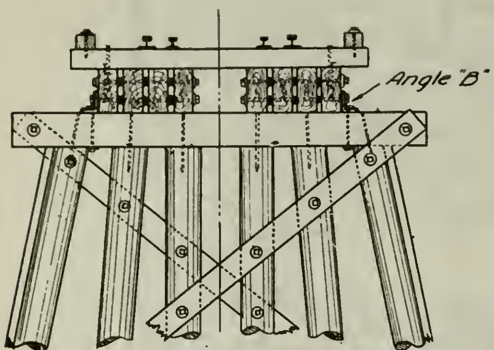


Typical Frame Bent

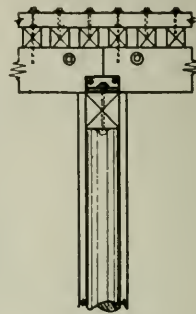
Typical Pile Bent

Floor Plan

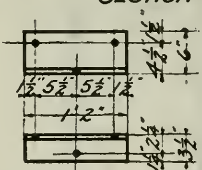
Exhibit 7



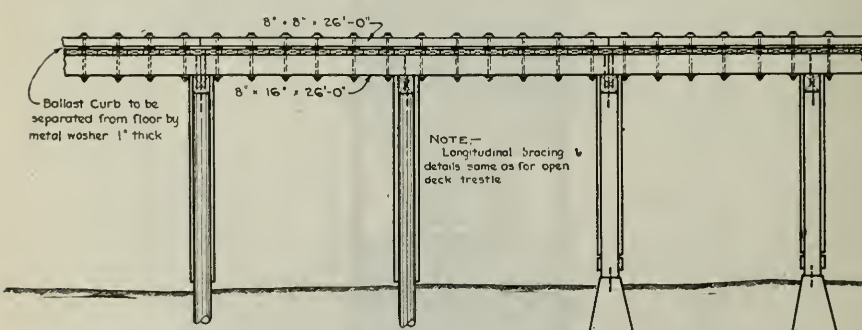
SECTION



ELEVATION



DETAIL OF ANGLE "B"
6"×3½"×½"-1'-2"



ELEVATION —TYPICAL PILE BENT

ELEVATION —TYPICAL FRAME BENT

Exhibit 8

No.	Rail Road	Panel Length	Limit Single Deck	Sills: Single	Sills: Double	Posts 1st Story: Plumb	Posts 1st Story: Batter	Posts 2nd Story: Plumb	Posts 2nd Story: Batter	Posts 3rd Story: Plumb	Posts 3rd Story: Batter	Posts 4th Story: Plumb	Posts 4th Story: Batter	Height of Story: 1st	2nd	3rd	4th	Transverse Bracing: Cross	Transverse Bracing: Sash	Transverse Bracing: Hor Fastened	Girts 1st Story: At Sash	1st Story: At Sill	2nd Story: At Sash	2nd Story: At Sill	3rd Story: At Sash	3rd Story: At Sill	4th Story: At Sash	4th Story: At Sill	Girts Bolted Spiked Dapped	Longitudinal Side Bracing Size: Single	Size: Double	Tower	Location	Bolted or Spiked	Date of Plans
1	Atchison T& St Fee	14'	25'	12"x12"		2	4		6					25'	25'			3"x10"	2: 3"x10"	Bolted	2: 6"x10"	2: 6"x10"	2: 6"x10"	2: 6"x10"					S.D	2 Lines 6"x10"			Intermediate Batter Posts	Bird Mouth	1904
2	A B & A	12'-6"			12"x12"	2	2	2	4					25'-4"	26'			3"x10"	2: 3"x10"	Bolt	2: 6"x10"	4: 8"x10"	2: 6"x10"	0					B		2 Lines 3"x10"	x All Panels	Plumb Posts	Bolt	1914
3	B & O	12'-6"	30'	12"x12"		2	2	2	2					30'	30'			3"x10"	3: 3"x10"	Bolt	2: 6"x10"	4: 6"x10	2: 6"x10	0					B & D		2 Lines 3"x10"		on Batter Posts	Bolt	1919
4	Canadian Northern	15'-0"			12"x12"		6		6		6		6	25'	24'-10"	24'-10"	24'-10"	3"x10"	2: 3"x10"	Ends bolt Interm Spiked	4: 5"x8"	6: 10"x10"	4: 5"x8"	6: 10"x10"	4: 5"x8"	6: 10"x10"	4: 5"x8"	6: 8"x8"	B & D.		4 Lines 3"x10"		4 Outside Batter Posts	B & S	1919
5	Canadian Pacific	15'-0"	35'		10"x12"		4		4		6		6	25'	24'-6"	24'-6"	24'-6"	3"x10"		Ends bolt Inter Spiked		4: 8"x12"		4: 8"x12"		4: 8"x12"			B & D		2 & 4 Lines 3"x10"		2 Outside Posts 4 " Posts	B	1906
6	C of Ga.	12'-6"	32'		12"x12"	2	2	2	4					29'	29'			3"x10"	2: 3"x10"	B & S	2: 6"x8"	4: 8"x10"	2: 6"x8"	0					B & D		2 Lines 3"x10"		Outside Posts	B & S	1919
7	Chicago & North West	13'		12"x12"		1	4	1	4	3	4			16'-5"	16'-3"	16'-3"		4"x10"		Bolts		4: 4"x10"		4: 4"x10"		2: 4"x10"			B		2 Lines 4"x10"		Outside Batter Posts	B	1912
8	C M & St P Rwy	15'-9"	45	12"x12"		1	4	1	4	1	4		6	31'-6"	31'-6"	31'-6"	31'-6"	3"x12"	2: 3"x12"	Spiked	2: 4"x12"	2: 6"x10"	2: 4"x12"	4: 6"x10"	3: 4"x12"	4: 6"x10"	4: 4"x12"	6: 6"x10"	S & D		2 Lines 3"x12"	x All Panels	Outside Posts	S	Not Approved
9	C & O.	12'-6"	22'		12"x12"	2	2	2	2					21'	21'			3"x10"		B & S		4: 6"x12"		0					B & D		2 Lines 3"x10"	x All Panels	on Plumb Post	S	1915
10	Copper Range R R	15'-9"	21'-6"	12"x14"		2	2	2	2					13'	15'			3"x10"		B & S		4: 6"x8"		4: 6"x8"					B & D		2 Lines 4 & 2 " 6"x8"				1901
11	Frisco Lines	14'	33'	12"x12"		1	4	1	4					32'	32'			3"x10"	2: 3"x10"	Ends B Inter S	2: 6"x10"	2: 6"x10"	2: 6"x10"	0					B & D	2 Lines 6"x10"			On Outside Post	B	1907 Revised to date
12	G T P R R	15'	32'-6"	12"x12"		3	2	3	2	3	4	3	4	24'	25'	25'	25'	3"x10"	2: 4"x10"	Ends B Inter S		3: 6"x10"		4: 6"x10"		4: 6"x10"		4: 6"x10"	B & D		4 Lines 6"x10"		4 Outside Posts	B	1906
13	G N R R	14'	33'-0"	12"x12"		2	4	2	4					32'	32'			3"x10"	2 Lines 2-3"x10"	Ends B Inter S	4: 6"x8"	2: 6"x8"	4: 6"x8"	0					B & D	2 Lines 6"x8"			Outside Posts	B & S	1914
14	I. C R R	14'	29'	12"x12"			4	1	4		6			23'	23'	28'		3"x10"	2: 3"x10"	B	2: 4"x12"	2: 4"x12"	2: 4"x12"	2: 4"x12"	2: 4"x12"				B		2 Lines 3"x10"		Outside Posts	B	1906
15	L & N. R R.	12'	Single Post Up to 62'																																
16	M & St L R R	13'-9"					[illegible]		6					31'-6"	31'-6"			3"x12"	2: 3"x12"	S.	At Top 4-4"x9"	4: 4"x9"	At Top 4-4"x9"	4: 4"x9"					S		2 Lines 4"x9"		Outside Posts	S	1899
17	M P R R.		Single Post Up to 40'			4																													
18	N Y C R R.		31'	12"x12"		2	2	2	4					30'	30'			3"x10"	2: 3"x10"	S.		4: 4"x12"							B & S		2 Lines 3"x10"		On Outside Posts	B & S	
19	N S R R	12.5		12"x12"		2	2	2	2	2	2			17'	19'	19'		3"x10"		B		2: 6"x10"		3: 6"x10"		2: 6"x10"			D	2 Lines 3"x12"			Outside Posts	B	1914
20	N & W R R.	25'		2: 6"x12"		4 Knee	2 Braces	2	4	2	6	2	6	19'-6"	25'	25'	25'	2"x10"		Ends B Inter S		2: 6"x12"		4: 6"x10"		4: 6"x10"		4: 6"x10"	B & D		4 Lines 3"x12"	x All Panels			1919
21	N P R R.	15'		12"x12"		6		6		6.		6		24'	24'	24'	24'	3"x10"	2: 3"x10"	Ends B Inter S	2: 6"x10"	2: 6"x10"	2: 6"x10"	2: 6"x10"	2: 6"x10"	2: 6"x10"	2: 6"x10"	2: 6"x10"	B & D	2 Lines 6"x10"			On 2 Inter Posts	B & S Bird Mouth	1912
22	Penna R R	14'	26'	12"x12"		2	2	4	2					25	25			3"x10"	2: 3"x10"	B	2: 4"x8"	2: 4"x8"	2: 4"x8"	2: 4"x8"							2 Lines 3"x10"	x All Panels	On Outside Posts	B	1913
23	S A L R R	12'-6"	42'	12"x12"		3	2	1	4	1	4		6	20	20	20	20	3"x8"		Ends B Inter S		2: 6"x8"		3: 6"x8"		3: 6"x8"			BS & D		2 Lines 3"x8"	x All Panels	On Outside Posts	B	1920
24	Southern R.R.	13'-6"		12"x12"		2	2	2	2									3"x10"		B		3: 8"x12"							B & D	2 Lines 3"x10"		x All Panels	On Outside Posts	B	1905
25	South & Western	12'-0"	30'	12"x12"		2	2	2	2					30	30			3"x10"	2: 3"x10"	B	2: 4"x12"	4: 6"x10"	2: 4"x12"							2 Lines 3"x10"			On Outside Posts	B	1906
26	Western Maryland			12"x12"		1	4	1	4					19'-6" 23'-6"				4"x10"	2: 4"x10"	B	4: 6"x10"	4: 6"x10"	4: 6"x10"						B.		2 Lines 4"x12"		On Outside Posts	B	1903

Appendix C

(3) BEST METHOD OF FIREPROOFING WOODEN BRIDGES AND TRESTLES

C. S. Heritage, *Chairman;* E. M. Lewis, C. H. Blackman, O. C. Badger, *Sub-Committee.*

Fire protection on all classes of railway structures is of utmost importance. This is especially true of bridges. The loss to a railroad on account of a burned bridge usually far exceeds the value of the bridge itself, because the line of traffic is obstructed and the railroad does not fully function until traffic can be resumed over the burned structure.

Wood is an inflammable material and a fire hazard always exists when wooden bridges are used. This hazard can, however, be reduced to a minimum.

Your Committee has, through a questionnaire, endeavored to ascertain the practice of the various railroads in regard to fireproofing wooden bridges and the results obtained from the use of different forms of fire protection, as well as the advantages of and objections to the various forms of fire protection that had been tried.

Answers were received from fifty roads, aggregating approximately 139,000 miles.

It is well established that the great majority of railway bridge fires are started from sparks or from hot coals dropped from locomotives. From the best information available, we believe this source to cover fully ninety per cent of all bridge fires.

Other sources of bridge fires are: Fires from brush or weeds burning around bridges; forest fires; tramps; lightning; fires from oil burning on water under bridges; incendiary; fires from dropping lighted cigarettes; fires from hot coals thrown out of dining cars and fires spreading from burning buildings or other outside sources. Of these sources, other than fires from locomotives, fires from burning brush and weeds are most frequent.

From this it appears that the principal sources of fires to guard against are fires starting from locomotives and to a less degree, fires starting from burning brush and weeds.

Fires from locomotives will be guarded against if the deck is so protected that if hot coals should drop from the engines, they cannot reach the timber. Fires from burning brush and weeds will be guarded against if the ground is cleared of this growth for a sufficient distance around the bridges. If these two precautions are taken, the bridge is reasonably protected from ordinary sources of fire.

Various forms of fire protection are used on the decks of bridges to keep hot coals from setting fire to the timber, such as ballasted decks, sheet metal over ties or both over ties and guard timbers, sheet metal over stringers and caps, gravel or rock covered decks and by the use of fire-resisting paint.

Of these the ballasted decks is the most favored. It has other advantages as well as being a very efficient protection against fires and its use is increasing among roads that maintain a considerable amount of timber trestles. Twenty-four roads reported using ballasted deck trestles. It is standard construction for seven roads and used extensively on several others. It is the most generally favored construction for furnishing an effective fire protected deck.

Covering decks with sheet metal was reported in use on seventeen roads, of which seven used it extensively and two reported having discontinued the use of it. It is effective when well maintained. The objections are that it is difficult to hold in place and makes inspection difficult. Also the life is not as great as the life of the structure when ordinary thin sheets are used.

Covering caps and stringers with sheet metal was reported in use by twenty-one roads. It is standard construction on seven roads. Four roads have discontinued the use of it. It is effective when well maintained but does not protect the ties. It is generally considered to lengthen the life of the timbers by keeping moisture out as well as protecting them from fire caused by dropping coals, althought one road reports that the timbers do not last as well when covered with sheet metal. If thin metal is used it does not last as long as the structure. It is subject to destruction from brine drippings. It is difficult to hold in place and makes inspection of timber difficult.

The use of a solid floor covered with gravel or crushed rock was reported in use by twenty roads but only three used it extensively. It was standard on one road and had been discontinued on one road. It protects the deck effectively when well maintained. The opinions of the various roads were divided, some claiming good results and others unsatisfactory results. The objections are that it is difficult to keep the gravel evenly spread over the floor, the vibration and draft from moving trains causing it to shift leaving bare places on the floor; it holds moisture, hastening the decay of the floor timbers; it gets under the rails and cuts the timbers, especially at the joints; it will not stay spread properly over the floor when the track has a superelevation to provide for curves.

The use of fire resisting paint was reported by 16 roads. It is used extensively on three roads and is standard on one road. It has been tried experimentally on ten roads and discontinued on one road. The general opinion is that it is effective against ordinary fires for a period of three or four years after its application, although some roads reported that it was not effective and of little value. It is probably a good protection to the timber, but to be entirely effective must be applied every three or four years. It will also keep the timber in better condition, thereby lessening the likelihood of its catching fire.

Other forms of fire protection, such as the covering of decks with roofing material, sanding or grouting the tops of ties or timbers were mentioned, but reports were too meager to draw any conclusions as to the value of these treatments.

To prevent fire starting from burning brush and weeds it is necessary to keep the right-of-way clear of undergrowth in the vicinity of wooden bridges. All brush and weeds should be kept cut at least 25 feet away from the bridges both underneath and on the embankments around the ends of the bridges and the sod removed under the bridge to a distance of at least three feet outside of any timber in the structure.

All wooden bridges should be provided with some form of fire fighting apparatus. It is usually impracticable to provide elaborate equipment for fighting a fire that has gained great headway. Our efforts along this line should be directed toward fighting fires in their incipiency, thus preventing the larger fires. For this purpose, it will usually be sufficient to provide water barrels and buckets for all wooden bridges, using one barrel for each bridge 50 feet long or less and one additional for each 150-foot length of bridge. In freezing weather the water in the barrels must be treated with salt or calcium chloride to prevent freezing. Fire buckets having round or conical shaped bottoms with a small hole in the bottom should be used. These are of less general utility than ordinary buckets and are not so likely to be stolen. On freshly creosoted structures, sand boxes with shovels can be substituted for water barrels and buckets to advantage. The sand must be kept dry to prevent freezing in cold weather. More elaborate fire-fighting facilities such as fire extinguishers, hose where water supply is available and watchman service may be provided in special cases where conditions warrant.

On overhead wooden roadway bridges, general precautions against fire should be taken as on wooden railroad bridges; that is, keep weeds and brush cut away from the timber and protect the timbers over the track where they are likely to catch fire from locomotives, by covering with sheet metal or painting with fire resisting paint.

The fire hazard on long wooden bridges can be reduced by introducing fire walls, one or more panels of concrete slab trestle, or other suitable barriers, at intervals along the bridge.

The use of creosoted timbers for railroad bridges is increasing. Timber when freshly creosoted is more inflammable than untreated timber, however, after it has been in service one or two years and the surface oils have dried out, it becomes a safer material than untreated timber.

On old bridges where timbers have started to decay, all loose and decayed timbers should be adzed off. Such conditions not only furnish a place for loading of hot cinders but timber in this condition is more easily ignited than good timber. Such conditions have been the direct cause of the beginning of many bridge fires.

Your Committee offers the following recommendations as good practice for fire protection on wooden bridges and trestles:

Recommendations on Fireproofing

All locomotives shall have adequate and well maintained spark screens in the front end and ash pans shall be maintained with a tight fit so that fires and hot coals cannot drop out.

The decks of wooden bridges shall be protected from fires starting from hot coals dropped from locomotives, preferably by adopting ballasted deck trestles; otherwise, by covering the deck with rust resisting sheet metal or covering the stringers and caps with rust resisting sheet metal.

When ties or other timbers are exposed, all decayed timber shall be kept trimmed off.

All brush and weeds shall be kept cut down for a distance of at least twenty-five feet from the bridge, both underneath and on the embankment at the ends of the bridge. Also all sod shall be removed from under timber bridges for a distance of three feet outside of the timber.

Water barrels with buckets shall be maintained on all timber bridges. one barrel each for structures up to 50 feet long and one additional barrel for each additional 150 feet.

On long bridges it is advisable to protect the bridge by introducing fire barriers at intervals of about 400 feet. This will reduce the hazard by preventing loss of the entire strueture in case of fire.

Special fire fighting apparatus and watchman shall be employed in unusual cases where conditions warrant.

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REPORT OF COMMITTEE XXI—ON ECONOMICS OF RAILWAY OPERATION

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D. L. Sommerville,
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C. C. Williams,
Louis Yager,

Committee.

To the American Railway Engineering Association:

Of the seven subjects assigned to it the report of your Committee, submitted herewith for your consideration, covers the following:

(2) Methods for increasing the traffic capacity of a railway.

(3) The effect of speed of trains upon the cost of operation.

(4) Methods for analyzing costs for the solution of special problems with which this Committee is concerned.

(6) The economical operation of trains against the current of traffic on multiple track railroads.

(7) Begin the study of methods for the determination of proper allowances for maintenance of way expenses due to increased use and increased investment, collaborating with Committee on Records and Accounts.

The Committee has not been able to complete the work assigned to it, with the exception of Subject No. 6. This subject has been very fully covered by the Sub-Committee, with the assistance of the members of the Association. The report is contained in Appendix "D," with definite recommendations.

Considerable study has been given by a Sub-Committee to Subject No. 5, "The feasibility and economy of through routing of solid trains and its effect on the capacity of terminals," but the Sub-Committee is unable to report this year. It is hoped that the result of the investigation of this subject will appear in the report of this Committee for the year 1923.

Reports of Sub-Committees on Subjects 2, 3, 4 and 7 are contained in Appendices "A," "B" and "C."

Attached as Appendix "E" is a report comparing the operation of one-engine and two-engine trains with three-engine trains, over the west end of the Cumberland Division of the Baltimore & Ohio Railroad.

The result of these tests is of some interest to operating officers having to operate mountain grades with heavy tonnage movements. The report was prepared by Mr. J. E. Teal, member of the Committee, and is published for the information of the Association.

ACTION RECOMMENDED

1. That the conclusions of the Committee given in Appendix D, relating to the economical operation of trains against the current of traffic on multiple track railways, be approved and published in the Manual.

Recommendations for Future Work

The Committee recommends the reassignment of Subjects Nos. 2, 4, 5 and 7.

Respectfully submitted,

THE COMMITTEE ON ECONOMICS OF RAILWAY OPERATION,

L. S. ROSE, *Chairman*.

Appendix A

METHODS FOR INCREASING THE TRAFFIC CAPACITY OF A RAILWAY

G. D. Brooke, *Chairman;*
H. H. Garrigues,
E. E. Kimball,
F. G. Nicholson,
J. L. Wilkes,
Sub-Committee.

Last year the report of this Sub-Committee dealt in part with a few of the physical elements which more or less determine the capacity of a railroad. The discussion was largely academic and requires results of actual operations to prove its value. For this reason the Sub-Committee undertook to collect data on the physical characteristics of a number of different roads and the traffic which was being handled, for the purpose of noting to what extent the theory was applicable to practical operation. Replies to a questionnaire have been received covering the characteristics and operating data of 23 operating districts. Every case presents an interesting problem, but most of them are so complex that it has not been possible to show the application of the principles to each one.

It has, therefore, been decided to use one or two of the simpler cases which have been worked up to develop the theoretical discussion a step or two farther so that next year wider applications of the theory can be made. That is to say: Next year it is proposed to show the application of these principles to the economic development of a railroad taking into account the growth of traffic through various stages, requiring changes in motive power, additional running tracks, grade revision, signals, etc., and to attempt to show the effects of these changes upon capital expenditures and operating expenses.

NOTES ON THE DETERMINATION OF THE TRAFFIC CAPACITY OF SINGLE AND MULTIPLE TRACK RAILWAYS

(Second Paper)

It was pointed out in the discussion last year that *traffic capacity* refers to the tonnage which can be moved regularly over a given arrangement of tracks in a given time. It depends on track capacity and operating methods. The latter are influenced by ruling grades, size of equipment, character of service, etc.

Track Capacity theoretically is fixed by the arrangement of tracks and passing sidings, and is measured in terms of train-hours per day (or month) per mile of line (or per division). It is based on the assumption that the arrangement of tracks is laid out for perfect operation and that full use is obtained of all passing sidings or other track facilities. In actual operation the arrangement of tracks is not always the best and it cannot be expected that train operations will be perfect, consequently full use will not be obtained from all of the passing sidings and track facilities.

The use which can be obtained in practice from given track facilities depends upon the character of service and no doubt varies with different roads having different methods of operation. It will be difficult to find identical conditions on any two roads, consequently the results obtained from one road may not be applicable to another, but if the actual use obtained from given track facilities or the actual track capacity determined by different railroads is compared with the theoretical track capacity, a useful criterion can no doubt be established which will be valuable in deciding when it will be most economical to provide new facilities.

This year, profiles, track layouts and operating statistics were obtained from a number of different railroads having busy single and double track sections. The Committee has been unable to work up enough of this data to draw final conclusions, but the methods of attack are no doubt instructive, and possibly if some of the roads which are faced with the necessity of installing new track facilities can apply some of the principles discussed to their problems, valuable conclusions can be drawn therefrom.

Determination of Theoretical Track Capacity.

Probably the best way to explain what is meant by the theoretical track capacity of a line is to consider Divisions A, B, C and D, Fig. 1. Divisions A and B are essentially single track lines having 24 and 21 passing sidings between the ends of the double track sections, respectively. There are 25 and 22 stretches of single track between terminals, or one more than the number of passing sidings. (Lap sidings for the present are counted as one.) To obtain the theoretical track capacities of these divisions assume that the sidings are located so that perfect operation is possible, that all trains make the same speed and that full use can be made of all passing tracks. Thus the theoretical track capacities of the single track sections of Divisions A and B are $25 \times 24 = 600$ and $22 \times 24 = 528$ train-hours per day, respectively. (See page 745, Proceedings A.R.E.A., Vol. 22, 1921.) It is also essential to assume that the passing sidings are long enough to accommodate but one train. If it is found by comparing the average length of sidings with the average length of train that the sidings are twice as long as the trains, or if there are lap sidings, then the theoretical track capacity is equal to twice the values found above. That is, it will be possible to accommodate two trains in each siding and thereby be able to operate trains in fleets. This is equivalent to installing passing sidings half the distance apart. (See last year's report.)

Thus, to arrive at the theoretical track capacity of a single track line in train-hours, divide the total length of passing sidings by the length of train it is proposed to operate to obtain the equivalent number of intermediate sidings. Increase this number by one and multiply by 24 to obtain the total train-hours per day for the division.

Divisions C and D include some double track. If the length of double track plus the length of sidings does not exceed 50 per cent of the length of the division it is possible to find the theoretical track capacity in the same manner, assuming the second track is split up into sidings equal to the length of trains and distributed throughout the division.

If the length of double track plus the length of sidings is more than half the length of the division, we have assumed that the theoretical track capacity will be expressed in terms of the double track capacity estimating the double track capacity on the basis of trains one train length apart on each track. (See page 745, Proceedings A.R.E.A., Vol. 22, 1921.) That is, the theoretical double track capacity in train-hours is equal to 12 times the number of tracks times the miles of second track and sidings divided by the length of train expressed in miles. On double track sections minimum train spacings may be determined by block signals, in which case the rule should be changed and length of block section substituted for length of train.

Table I gives details of operating statistics necessary for estimating the theoretical track capacity.

Determination of Actual Track Capacity.

When a road reaches the point where train movements are seriously interfered with on account of limited track facilities, we will assume the conditions then existing represent the actual track capacity of the division. The period of greatest movement can then be selected and analyzed to establish a measure of the actual track capacity. Obviously in the beginning a road must have reached this point before its actual track capacity can be determined. When the actual track capacity has been established for a number of different roads it is felt that it will be possible to determine certain criteria and relationships between various factors of train operations which will make it possible to forecast the actual capacity of similar roads before they reach the limit of their present facilities.

The actual track capacity will be very much less than the theoretical for the reason that we have elected to base the theoretical track capacity on the most favorable conditions. In practice, conditions must be taken as we find them. Trains do not run at a uniform speed, passenger trains and freight trains run at different speeds, and when the two services are maintained there will be more or less interference of one with the other, tending to restrict the time when the running tracks can be used.

Furthermore, due to the fact that passing sidings are laid out so that the running time is not uniform between all sidings, it is impossible to obtain full use from all of the track facilities. The section which takes the longest time for a train to run over it in both directions determines the number of trains which can be operated over the division. It will thus be seen that the actual track capacity can often be improved by a rearrangement of sidings.

TABLE 1—COMPARING ACTUAL TRAIN-HOURS OPERATED WITH THE THEORETICAL TRAIN-HOUR CAPACITY

ITEM	A	B	C	D	E	
1. Length of Division	138	124	132	117	111	
2. Miles of double track	11	10	51	56	....	
3. Number of passing sidings	24	22	18	14	17	
4. Average miles between sidings	5.1	5.0	4.3	4.1	6.5	
5. Maximum miles between sidings	8.5	8.8	6.5	5.1	10.0	
6. Miles of passing sidings	17.8	17.2	15.0	17.0	11.0	
7. Total miles of track	166.8	151.2	198.0	190.0	122.0	
8. Number of cars per train	60.	60.	60.	60.	80.0	
9. Length of train, feet	2400	2400	2400	2400	3200	
11. Theoretical track capacity, train-hours	*1544	*1460	†3485	†3854	*460	
12. Actual train-hours operated. Date	Aug., 1920	Jan., 1920	Aug., 1920	Jan., 1920	April 1915	1919
Train-hours, freight	10,000	10,835	10,415	7,793	2,236	1,402
Train-hours, passenger, estimated	580	506	846	729	409	409
Train-hours, maximum month	10,580	11,341	11,261	8,522	2,645	1,811
Average train-hours per day	341	366	363	275	88	60
13. Ratio of actual train-hours to theoretical capacity	.222	.250	.104	.071	.191	.130
14. Gross ton miles divided by miles of road	29,750	34,150	55,100	38,600	....	
15. Ave. train miles divided by miles of road	27.9	27.7	28.0	24.0	....	

$$\text{*Train hours} = \left[\frac{(\text{Item 2} + \text{Item 6})\ 5280}{\text{Item 9}} + 1\right] 24$$

$$\text{†Train hours} = \frac{(\text{Item 2} + \text{Item 6})\ 5280}{\text{Item 9}} \times 2 \times 12$$

provided there are no signals spacing trains farther than one train length apart.

On Divisions A and B, Fig. 1, the longest stretch of single track between sidings is 8.5 and 8.8 miles, respectively. If there were but one class of trains operated over these divisions and the speeds were uniform over the entire division the maximum number of trains which could be on the line at any one time would be the same as if all the sidings were the same distance apart, namely 8.5 and 8.8 miles, respectively; that is, from this cause alone the track capacity is reduced from 600 and 528 train-hours per day to 384 and 213 train-hours per day, respectively. Suppose the trains took eight hours to run between terminals and ¾ hour to run over the longest section, then there could only be $24 \div \frac{3}{4} = 32$ trains operated per day, or a capacity of $8 \times 32 = 256$ train-hours per day.

The actual sidings at each end of the longest sections may be long enough to accommodate two or more trains at a time, in which case we would expect that actual operations could be adjusted to fit the conditions, and a somewhat greater capacity than 256 train-hours could be obtained.

Table I gives a comparison of the actual with the theoretical track capacity, assuming these divisions are operating up to full capacity. The actual train-hours reported cover operations over the single and double track sections because data could not be obtained which would show the actual train-hours operated over each section. It is much better to con-

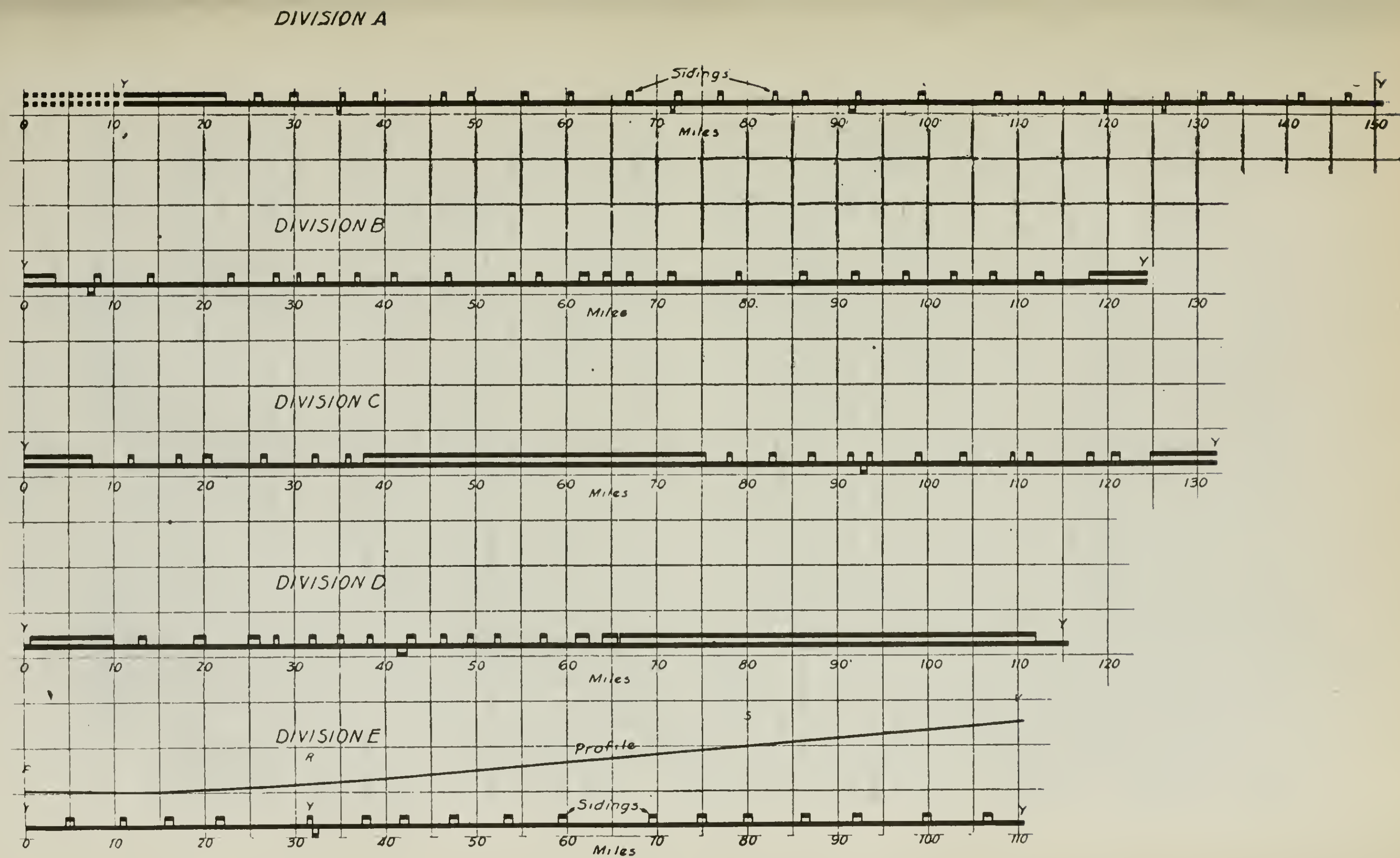


FIG. 1—TRACK CHARTS OF FIVE ENGINE DISTRICTS.

sider the track capacities of the single and double track sections separately because the capacity of the single track section always limits the capacity of the division. Likewise, if some trains branch off at junction points between terminals the actual train-hours for various sections where the train density is different should be obtained separately.

There is only a light passenger service operated over these divisions and the train-hours consumed by passenger trains on the road are estimated from time-table schedules. On Division A the passenger run is longer than the freight, as indicated by the dotted lines, but the passenger train-hours are estimated to cover only the freight division.

Comparing the actual train-hours per day with the theoretical capacity it will be noted that the single track sections are being operated nearer to capacity than the double track sections. The gross ton-miles per mile of road is greatest for the sections having the greatest amount of double track, but the train-miles per mile of road differs little on any of the sections. There is more passenger service on Division D, particularly on the double track section, than on the other divisions, a fact which no doubt accounts for much of the double track on this division. How much nearer it is possible to approach the theoretical values than are shown by the ratios for the single track sections is problematical. What effect extending the double track will have in reducing the running time of trains would be very interesting to watch, if such plans are being considered.

The comparisons in the above table are based upon the daily average of the maximum month's operation. The maximum movement for a shorter period may show greater utilization of track facilities and it would be interesting to apply these principles to shorter periods of record movements to see what effect limited track facilities have upon train movements under these conditions or how record movements are brought about. On the other hand, the maximum daily movement which can be handled over a given division is of very little value unless nearly equal movement can be repeated day after day without causing congestion.

Usually the best criterion for judging the traffic capacity of a division is the traffic which it can handle regularly for a period of 15 days or a month. In this connection Fig. 2 shows the average road time per train plotted against the average number of trains per day (assuming the number of trains equals train-miles per mile of road per day) for 22 months.

At first glance it would appear that there is no relation between the time taken per train to cover the road and the number of trains on the road per day. However, by symbolizing the various points so as to distinguish between summer and winter operation, Government control period and months of different years, those familiar with the conditions of operation at those times can no doubt explain many of the irregularities.

Without attempting to analyze the charts it will be seen that the road time for 1921 shows improvement over 1920, that operations are appreci-

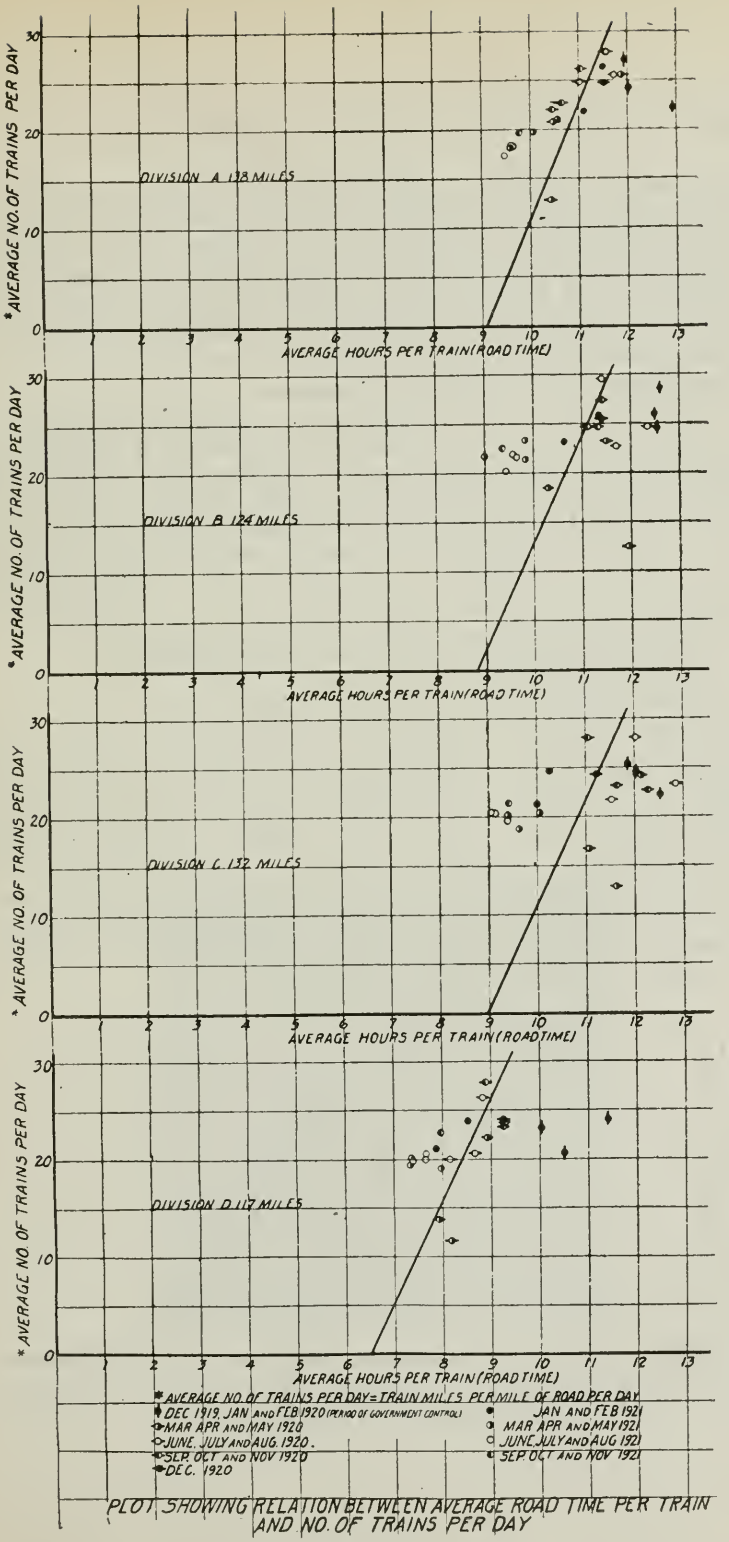

DIVISION A 138 MILES
DIVISION B 124 MILES
DIVISION C 132 MILES
DIVISION D 117 MILES
* AVERAGE NO. OF TRAINS PER DAY
AVERAGE HOURS PER TRAIN (ROAD TIME)
* AVERAGE NO. OF TRAINS PER DAY = TRAIN MILES PER MILE OF ROAD PER DAY
DEC 1919, JAN AND FEB 1920 (PERIOD OF GOVERNMENT CONTROL)
MAR APR AND MAY 1920
JUNE, JULY AND AUG. 1920.
SEP. OCT AND NOV 1920
DEC. 1920
JAN AND FEB 1921
MAR APR AND MAY 1921
JUNE, JULY AND AUG 1921
SEP. OCT AND NOV 1921
PLOT SHOWING RELATION BETWEEN AVERAGE ROAD TIME PER TRAIN AND NO. OF TRAINS PER DAY

FIG. 2.

A

ably affected by weather conditions, especially by winter temperatures. The important relation it is intended to show by these charts is the tendency for every train to consume more time on the road, the greater the number of trains on the road per day. This tendency is indicated by the slope of the lines drawn through the middle of the group of points. This relation is brought out in the methematical development of the theory of train operation discussed in the Exhibit.

Simplification of the Train-Hour Diagrams.

Last year a method of plotting actual train-hour and crew-expense diagrams was discussed. The method of obtaining and arranging the data for these charts is tedious and it is felt that some simpler method can be developed which will make it possible to obtain the data with much less effort and at the same time establish mathematical relationships which can be simplified. The scheme briefly is to find the equation of the train-hour diagram and to ascertain if the results obtained by empirical formulas are close enough to the actual to be of practical value.

Similarity Between the Typical Train-Hour Diagrams and Probability Curve.

Train operations have in them the element of luck, that is, every train—after it leaves a terminal—runs a chance of being delayed from one cause or another. Some trains will be delayed more than others and the time which a train consumes on the road depends largely upon various combinations of circumstances. It is, therefore, logical to assume that an equation in the form of the Probability Curve $y = ke^{-(nx)^2}$ will most nearly fit the curve of a train-hour diagram. The origin of coordinates for such a curve is (0, 0) and the curve is symmetrical both sides of the y axis, as shown in Fig. 3. The typical train-hour diagram is obtained by using only half of the probability curve and substituting a rectangle for the other half, as indicated.

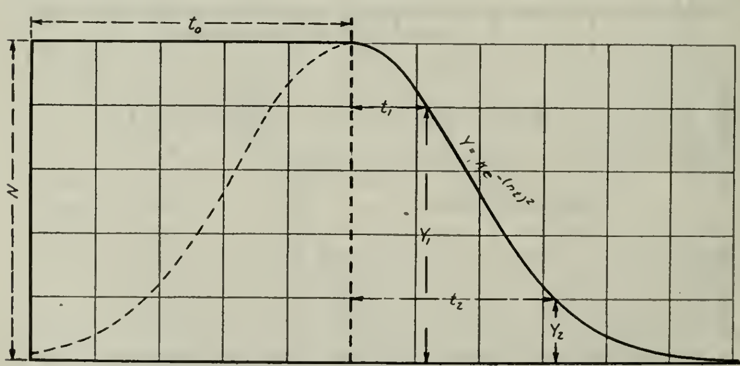


Fig. 3—Diagram Showing Development of the Typical Train-Hour Diagram from the Probability Curve.

In this connection it is interesting to note how closely the theoretical values in Table 2 agree with the values obtained in actual operation. Data for plotting the actual train-hour diagrams were obtained from train dispatcher's sheets for two months for Division E, Fig. 1. The division was subdivided into three sections, P-R, R-S and S-V, and actual train-hour diagrams plotted as shown. Two points (as indicated) on each one of these curves were used to derive the equation of the probability curve and compute the theoretical values. (See Exhibit A for explanation of methods employed.)

The total train-hours from the actual records are given in the following table, together with the theoretical train-hours calculated from the equations of the curves. In no case is the difference between the area of the actual and theoretical train-hour diagrams more than 2 per cent, which is much closer than would ordinarily be expected from empirical formulas.

TABLE 2—COMPARATIVE DIMENSIONS OF ACTUAL AND THEORETICAL TRAIN-HOUR DIAGRAMS ILLUSTRATED IN FIG. 4

	P-R (31.3 *Miles*)		*R-S* (48.7 *Miles*)		*S-V* (30.7 *Miles*)	
	Actual	*Theo.*	*Actual*	*Theo.*	*Actual*	*Theo.*
N	125	125	136	136	135	135
t_0	1.250	1.207	2.000	2.638	1.000	1.736
n	.....	.868	.....	.501	.....	.7955
Area (train-hours)	281.0	278.5	589.7	599.3	378.5	384.9
Ave. hrs. road time	2.248	2.227	4.335	4.405	2.803	2.850

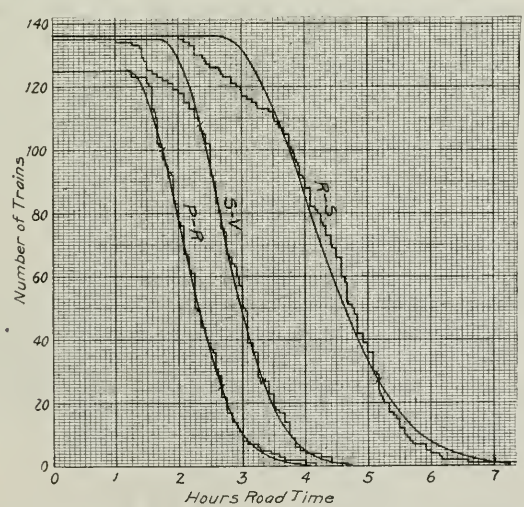


FIG. 4—ACTUAL AND THEORETICAL TRAIN-HOUR DIAGRAMS, SECTIONS P-R, R-S, S-V, DIVISION E, FIG. 1.

CONCLUSIONS

1. The Committee has not been able to analyze sufficient data to show how close it is possible to approach the theoretical limit of track capacity in actual practice. Two essentially single track divisions with very few passenger trains have been partially analyzed, but the conclusions which can be drawn from the analyses of these two cases cannot be taken as final. Before making final conclusions it is important to know if there are any other divisions which are doing better with equal facilities and also to secure opinions from those operating these divisions regarding their estimates of how soon additional track facilities will be required.

These features deserve more study and it is suggested that those familiar with actual operating conditions on sections of track which are known to be operating nearly to capacity apply some of the principles here discussed to their conditions and favor the Committee with their conclusions.

2. It has been found that train operations can be represented by a mathematical law, the development of which is given in Exhibit A of this report.

3. The application of this law to different sets of observations makes it possible to compare several months' operation of a given division on a more equal basis. Likewise operations of different divisions which are more or less similar can be compared on more nearly the same basis.

4. By such comparisons it is felt that the effect of extreme weather conditions, greater track facilities, characteristics of motive power, character of commodities and supervisory methods on the average time on the road can be more accurately determined.

5. Exhibit A of the report is most important, because it is arranged for reference and shows how closely actual operations can be forecasted by applications of the mathematical theory.

Exhibit A

I—Derivation of Theoretical Train-Hour Diagram.

Let the equation of the theoretical train-hour curve be $y = ke^{-(nt)^2}$ where y = number of trains taking more than t hours to complete their runs, k = a constant and t = hours referred to a system of coördinates where $y = k$, when $t = o$. See Fig. 3. Then if k is known the coördinates of two other points (a and b) determine the curve. The number of trains considered determines k, hence if (y_1, t_1) and (y_2, t_2) are the coördinates of the two points a and b, respectively, then

$y_1 = ke^{-(nt_1)^2}$ and $y_2 = ke^{-(nt_2)^2}$

or $(nt_1)^2 = log_e \left(\frac{k}{y_1}\right)$ and $(nt_2)^2 = log_e \left(\frac{k}{y_2}\right) = n^2 (t_1 + c)^2$

since $t_2 = t_1 + c$.

This leaves two equations with two unknown quantities n and t_1, from which the following values are obtained:

$$t_1 = \frac{c\left[\log_e\left(\frac{k}{y_1}\right) + \sqrt{\left[\log_e\left(\frac{k}{y_1}\right)\right]\left[\log_e\left(\frac{k}{y_2}\right)\right]}\right.}{\log_e\left(\frac{k}{y_2}\right) - \log_e\left(\frac{k}{y_1}\right)}$$

$$\text{and } n^2 = \frac{\log_e\left(\frac{k}{y_1}\right)}{t_1^2}$$

$$t_1 + t_0 = t_1'$$

Where t_0 is the abscissa of the origin of the assumed system of coordinates referred to the origin of the train-hour curve and t_1' is the abscissa of the point a referred to the origin of the train-hour curve. Therefore $t_1' =$ hours on the road and is a known quantity.

If $N =$ number of trains considered, is substituted for k, then the calculations are best arranged in table form as given below:

TABLE

Item			Example Fig. 3
1	Total number of trains considered................	N	100
2	*Number of trains over t_2' hours (8.2)............	y_2	20
3	*Number of trains over t_1' hours (6.2)............	y_1	80
4	Time interval between t_2' and t_1'.................	c	2
5	*Ratio item (1)/item (2) $= N/y_2$................		5.
6	*Ratio item (1)/item (3) $= N/y_1$................		1.25
7	Log_e item (5)..................................		1,60944
8	Log_e item (6)..................................		.22314
9	Difference (item (7) — item (8))..............		1,38630
10	Product item (7) $\times$ item (8).....................		.3595
11	Square root item (10)..........................		.5995
12	Item (8) + item (11)..........................		.82264
13	Item (4) $\times$ item (12)..........................		1.64528
14	Item (13)/item (9).............................	t_1	1.187
15	t_1' of item (3) — item (14)......................	t_0	5.013
16	Item (8) divided by item $(14)^2$..................	n^2	.1584
17	Square root of item (16)........................	n	.398

*To obtain accuracy y_2 and y_1 should be selected so that the ratios N/y_2 and N/y_1 will be approximately 1.25 and 5.0, respectively.

To plot the curve arrange calculations as follows and plot values in outside columns:

$t' =$ $t_0 + t$	t_0	t	$(nt)^2 =$ Item (16) $\times t$	$e^{-(nt)^2}$ Note A	$Ne^{-(nt)^2}$
5.013	5.013	0		1.000	100.0
5.513	"	.5	.0398	.960	96.0
6.013	"	1.0	.1584	.870	87.0
7.013	"	2.0	.6336	.528	52.8
8.013	"	3.0	1.4256	.240	24.0
9.013	"	4.0	2.5344	.080	8.0
10.013	"	5.0	3.9800	.020	2.0
11.013	"	6.0	5.7024	.003	.3

NOTE A—Values of $e^{-(nt)^2}$ for convenience are given on curve sheet Fig. 5 for various values of $(nt)^2$.

II—Area of the Theoretical Train-Hour Diagram.

The area of the train-hour diagram is the sum of two areas, one the area of a rectangle having the dimensions k and t_0 and the other, one-half the area under the probability curve $y = ke^{-(nt)^2}$ between the limits $-\infty$ and ∞. If the area under the probability curve between the limits $-\infty$ and ∞ is taken as unity it can be shown that $k = \frac{n}{\sqrt{\pi}}$

For our purposes we will consider the area under the probability curve $y = ke^{-(nt)^2}$ between the limits o and ∞ equals unity, hence k will equal $\frac{2n}{\sqrt{\pi}}$ or the area of the train-hour diagram $= \frac{2n}{\sqrt{\pi}} (t_0 + 1)$ referred to some arbitrary unit of area.

On the basis of train-hours the area of the rectangle is Nt_0 or

$$Nt_0 = \frac{2nt_0}{\sqrt{\pi}} \quad \text{or} \quad \frac{N\sqrt{\pi}}{2n} = 1$$

or the area of the train-hour diagram in train-hours is

$$Nt_0 + \frac{N\sqrt{\pi}}{2n}$$

III—Area of the Theoretical Crew-Expense Diagram.

If the crews are paid on the basis of 100 miles or eight hours then all crews will be paid for a minimum of eight hours (if the run is not over 100 miles), and those on the road over eight hours will make overtime. Usually some of the trains get over the road in less time than the limit set for overtime to begin. If t'' represents the time when overtime begins, then the area of the crew-expense diagram is equal to the area of a rectangle having the dimensions N and t'' plus that part of the area of the train-hour diagram outside of the rectangle. Or mathematically

Area of crew-expense diagram =

$$Nt'' + \left(\frac{N\sqrt{\pi}}{2n}\right)\left[1 - \frac{2n}{\sqrt{\pi}}\int_0^{nt} e^{-(nt)^2}\,dt\right]$$

The values of the integral $\frac{2n}{\sqrt{\pi}}\int_0^{nt} e^{-(nt)^2}\,dt$ are given on curve sheet, Fig. 5, for various values of nt.

See also discussion Crew-Expense Diagrams in last year's report, Volume 22, page 751.

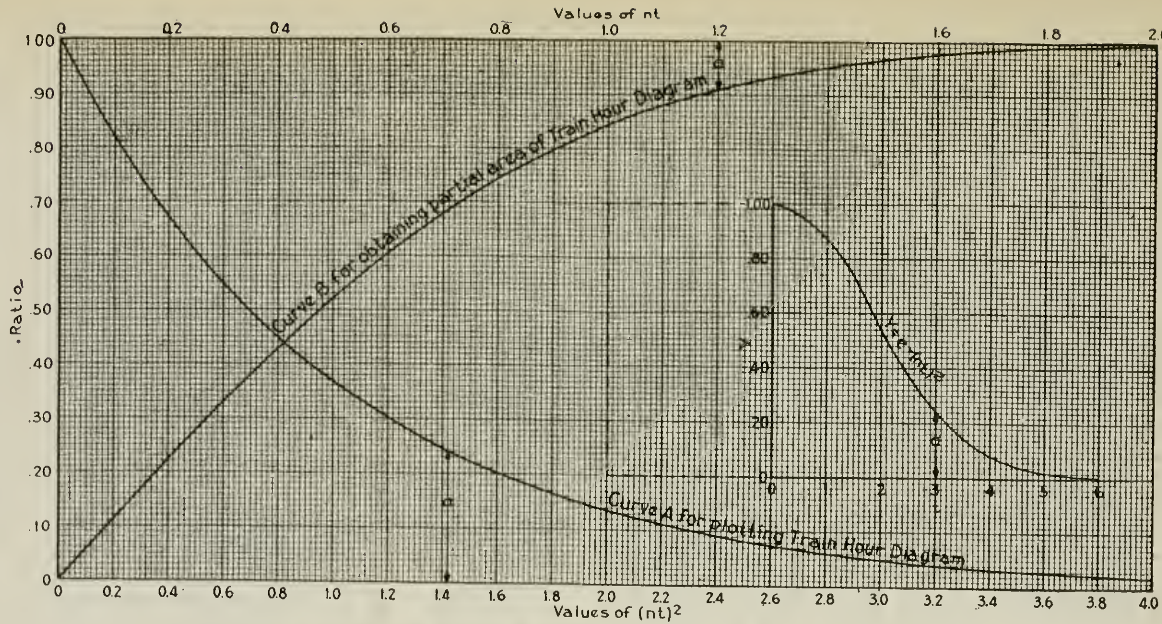
Example: Find the area of the crew-expense diagram Fig. 3

$$t'' = 8.$$
$$t_0 = 5.013.$$
$$t'' - t_0 = t = 2.987.$$
$$n = .398.$$
$$nt = .398 \times 2.987 = 1.189.$$

Ordinate of Curve B corresponding to $nt = 1.189 = .909$.

$8 \times 100 + \frac{100\sqrt{\pi}}{2 \times .398}(1 - .909) = 800 + 20.25 = 820.25$ train-hours paid for on eight-hour basis of pay, straight time for overtime.

$8 \times 100 + 1.5\frac{100\sqrt{\pi}}{2 \times .398}(1 - .909) = 800 + 30.38 = 830.38$ train-hours paid for on eight-hour basis of pay, time and one-half for overtime.



Example

To Plot Train Hour Diagram:-
In the equation $Y=e^{-(nt)^2}$ assume $n=.398$. Then for $t=3$, $(nt)^2=1.4256$, from curve 'A' ratio corresponding to $(nt)^2=1.4256$ is .24. Plot this value for $t=3$. Other points on the train hour curve found in the same manner.

To Find Partial Area of the Train Hour Diagram:-
1st - Calculate the area of the rectangular portion.
2nd - Total area under train hour curve $=\frac{\sqrt{\pi}}{2n}$.
3rd - Partial area between 0 and any point $t=3$ is found as follows assuming $n=.398$, $nt=.398\times3=1.194$. From curve 'B' the ratio corresponding to $nt=1.194$ (on top line) is .91. That is, the area under the curve between 0 and $t=3$ is 91% of the total area or $\frac{.91\sqrt{\pi}}{2n}$. If overtime occurs after $t=3$, the overtime area equals total area minus partial area.

Fig. 5.

IV—Effect of Various Operating Conditions Upon Dimensions of Train-Hour Diagrams.

Having determined the dimensions for a known set of operating conditions it is important to be able to forecast what the performance of trains will be, by constructing train-hour diagrams for different sets of conditions.

Suppose that Fig. 3 is the train-hour diagram found for a Division M_1 miles long operating N_1 trains per day and it is desired to ascertain what the performance will be if the length of division were changed to M_2 miles, the number of trains increased to N_2 trains per day or the speed of trains increased, assuming that other conditions remain constant.

If trains could be operated perfectly, which is the limiting case, the train-hour diagram in every case would be a rectangle, hence increasing the length of division without changing the number or speed of trains would lengthen the train-hour diagram; increasing the number of trains without changing the length of division or speed of trains would increase the height of the train-hour diagram; and increasing the speed of trains without changing the length of division or number of trains would decrease the length of the train-hour diagram. Hence changing any one of these conditions affects only one dimension of the perfect train-hour diagram, which is the rectangular portion of the theoretical or actual train-hour diagram.

Inasmuch as the remaining portion of the train-hour diagram reflects the delays to trains it is logical to assume that the longer the division, or the greater the number of trains the greater will be the delays to each train and the following discussion is for the purpose of setting forth mathematical expressions to show the effect of these conditions upon the average road time.

V—Effect of Length of Division Upon Average Road Time.

If M_1 and M_2 represent the miles per division and T_1 and T_2 represent the average road time of all trains and N_1 represents the number of trains operated (being the same in both cases), it can be assumed that if the character of profiles and track arrangement are identical the running time over equal distances will be identical if there are no delays. Likewise the delays in equal distances will be identical, or the average road time will be proportional to length of divisions.

That is $\frac{T_1}{T_2} = \frac{M_1}{M_2}$

$$T_1 = t_0 + \frac{\sqrt{\pi}}{2n_1} \text{ and } T_2 = t_0' + \frac{\sqrt{\pi}}{2n_2}$$

Substituting $\frac{T_2}{T_1} t_0$ for t_0'

$$\frac{n_2}{n_1} = \frac{T_1}{T_2} = \frac{M_1}{M_2}$$

That is, the values of n will be inversely proportional to the length of divisions.

VI—Effect of Number of Trains Upon Average Road Time.

If T_1 and T_2 represent the average road time of all trains corresponding to N_1 and N_2 trains per day it can be assumed that the delays to trains going the same distance will be proportional to the number of trains. Or the areas under the curve portions of the train-hour diagrams will be similar, that is, they will be proportional to the square of their linear dimensions.

$$\frac{\frac{N_1\sqrt{\pi}}{2n_1}}{\frac{N_2\sqrt{\pi}}{2n_2}} = \left(\frac{N_1}{N_2}\right)^2$$

$$\text{or } \frac{n_2}{n_1} = \frac{N_1}{N_2}$$

$$T_1 = t_0 + \frac{\sqrt{\pi}}{2n_1} \text{ and } T_2 = t_0 + \frac{\sqrt{\pi}}{2n_2}$$

$$\frac{T_2}{T_1} = \frac{2t_0n_1n_2 + n_1\sqrt{\pi}}{2t_0n_1n_2 + n_2\sqrt{\pi}}$$

substituting $\frac{N_1}{N_2}n_1$ for n_2 and simplifying

$$\boldsymbol{T_2 = \frac{2N_1t_0n_1 + N_2\sqrt{\pi}}{2N_1t_0n_1 + N_1\sqrt{\pi}} T_1}$$

If $N_2 = O$

$$T_2 = \frac{2t_0n_1}{2t_0n_1 + \sqrt{\pi}} T_1$$

$$= \frac{t_0}{t_0 + \frac{\sqrt{\pi}}{2n_1}} T_1$$

But $T_1 = t_0 + \frac{\sqrt{\pi}}{2n_1}$

Therefore $T_2 = t_0$ when $N_2 = O$.

Example.—If we assume that the straight lines in Fig. 2 show the relation between the number of trains and the average time on the road for the four divisions A, B, C and D, the intercepts of these lines with the horizontal axis will give the value of t_0. Then if N_1 and T_1 for any other point on the line are taken, the value of n_1 at this point can be calculated, also the average time on the road T_2 when there are N_2 trains on the road, as shown in the following table. The expression for T_2 gives the equations for these lines and it can be assumed that the reason why there are not more actual points on the line is because other conditions were variable.

	Div. A.	Div. B.	Div. C.	Div. D.
t_o	9.1	8.8	8.95	6.5
N_1	15	15	15	15
N_2	30	30	30	30
T_1	10.35	10.20	10.35	7.9
$n_1 = \frac{\sqrt{\pi}}{2(T_1 - t_o)}$	.715	.633	.633	6.33
T_2 by substitution in formula	11.59	11.60	11.75	9.3
T_2 from charts	11.62	11.60	11.75	9.35

VII—Effect of Speed With a Given Number of Trains Upon Average Road Time.

If T_1 and T_2 represent the average road time of all trains corresponding to S_1 and S_2 speed of trains then for a given length of division the minimum time on the road t_o and t_o', respectively, will be inversely proportional to the speeds.

$$\frac{t_o}{t_o'} = \frac{S_2}{S_1}$$

With a given arrangement of tracks and the same number of trains the delays will be the same in both cases or the area under the curve will remain the same

$$\frac{N_1\sqrt{\pi}}{2n_1} = \frac{N_1\sqrt{\pi}}{2n_2} \qquad \text{or } n_2 = n_1$$

The average time on the road in each case is as follows:

$$T_1 = t_o + \frac{\sqrt{\pi}}{2n_1} \text{ and } T_2 = t_o' + \frac{\sqrt{\pi}}{2n_2}$$

$$T_2 = \frac{2t_o'n_1 + \sqrt{\pi}}{2t_o n_1 + \sqrt{\pi}} T_1$$

Substituting

$$\frac{S_1}{S_2} t_o \text{ for } t_o'$$

$$T_2 = \frac{2S_1 t_o n_1 + S_2\sqrt{\pi}}{2S_2 t_o n_1 + S_2\sqrt{\pi}} T_1$$

Examples—Division E has been selected to show the application of the mathematical theory to actual operating results. As will be seen by reference to Fig. 1 this division has been divided into three sections P-R; R-S and S-V. The section P-R is practically level and the grade on the other two sections is nearly uniform about 0.4 per cent. The dimensions of the theoretical train-hour diagrams are given in Table 2 and as before explained were obtained from the actual train-hour diagrams made from data taken from the train dispatcher's sheets.

Let us suppose that we had obtained only the dimensions for the train-hour diagram for the section S-V, but that we knew the distances between P and R (31.3 miles), between R and S (48.7 miles), and between S and V (30.7 miles) and knew that the best speeds on the section P-R and R-S were respectively 46.6 per cent and 4.5 per cent faster than on section S-V, and that there were 125 trains operated over section P-R, 136 over section R-S and 135 over section S-V, would it then be possible to compute the dimensions of the train-hour diagrams for the sections P-R and R-S?

The procedure would be as follows (see example below):

Begin by assuming that the conditions of operation for the three sections P-R, R-S and S-V are the same except that the sections are not the same length. Values of t_0, n, and T for sections P-R and R-S are then calculated, correcting for the difference in length of sections. The next step is made to correct for the difference in the number of trains operated over each section, and the third step is for the purpose of correcting for the difference in speed of trains over the various sections.

Thus we have given for section S-V $M = 30.7$ miles, $N = 135$ trains. $S = 17.68$ M.P.H. $t_0 = 1.736$ hrs., $n = .7955$ and $T = 2.85$ hrs. For section R-S we have given $M = 31.3$ miles, $N = 125$ trains and $S = 25.93$ M.P.H from which to find t_0, n, and T corresponding:

Known factors, see Figs. 1 and 4	P-R	R-S	S-V
Miles (M_3) (M_2) (M_1)	31.3	48.7	30.7
Number of trains (N_3) (N_2) (N_1)	125	136	135
Best speed M.P.H. (S_3) (S_2) (S_1)	25.93	18.47	17.68
t_0			1.736
n			.7955
T average road time			2.850
First derived factors (correction for distance Art. V)			
N_1	135	135	
$t_0' = (M_3/M_1)\ t_0$ and $(M_2/M_1)\ t_0$	1.770	2.754	
$n' = (M_1/M_3)\ n$ and $(M_1/M_2)\ n$	.780	.5015	
T' average road time $= t_0' + \frac{\sqrt{\pi}}{2n'}$	2.905	4.520	
Second derived factors (correction for number of trains, Art. VI)			
N_3 and N_2	125	136	
t_0'' same as t_0'	1.770	2.754	
$n'' = (N_3/N_1)\ n'$ and $(N_2/N_1)\ n$	.842	.498	
T'' average road time $= t_0'' + \frac{\sqrt{\pi}}{2n''}$	2.822	4.535	
Third derived factors (correction for speed of trains, Art. VII)			
$t_0''' = (S_1/S_3)\ t_0''$ and $(S_1/S_2)\ t_0''$	1.207	2.638	1.736
n''' same as n''	.842	.498	2.850
T''' average road time $= t_0 + \frac{\sqrt{\pi}}{2n'''}$	2.250	4.420	2.850
Compare last two lines with the following from Table 2:			
n from table 2	868	.501	.7955
T from table 2	2.227	4.405	2.850

This comparison is interesting because it shows that the results obtained by the application of the theoretical laws are approximately the same as obtained in actual operation.

In most cases we look for much greater variations between the theoretical and actual results than shown above, because the procedure thus far only corrects for lengths of divisions, number of trains and train speeds. Other conditions, such as difference in track facilities, characteristics of motive power, supervision, etc., have their effect which we hope can be similarly analyzed and closer comparisons drawn between various methods of operation.

Appendix B

EFFECT OF SPEED ON THE COST OF OPERATION

Wm. G. Raymond, *Chairman;*
J. B. Babcock 3rd,
J. M. Burt,
Mott Sawyer,
J. E. Teal,
C. C. Williams,
Sub-Committee.

The work assigned to Sub-Committee No. 3 was the study of the effect of speed on the cost of operation.

As was done last year the work was divided into three parts:

1. Effect of speed on the cost of maintenance of way.
2. Effect of speed on the cost of transportation.
3. Effect of speed on the cost of maintenance of equipment.

No new data have been obtained nor do there appear to be any data available that have not been used. Certain tentative conclusions have been drawn from such data as were available and these conclusions are given to the Association that they may be proven or disproven by such experiment or analysis of accounts as the several members may wish, or be able to make. In the absence of disproving evidence, the conclusions are thought to be worthy of acceptance.

TENTATIVE CONCLUSIONS

1. Other conditions remaining unchanged, the cost of maintenance of way increases with increased speed of operation.

Exact relation has not been established nor can it be established alike for all conditions of track, roadbed, and traffic.

For minor differences in cost due to minor changes in speed not requiring changes in maintenance standards it may be assumed, until experiment proves otherwise, that the cost of maintenance of way varies with speed of operation as set forth in the report of this Committee in the Proceedings of 1921 at pages 760 to 772. For convenience the numerical values found in that discussion are repeated below in Table 1.

Table 1—Differences in Cost of Maintenance of Way Due to Minor Changes in Speed of Operation

Item	*For Passenger Trains*		*For Freight Trains*	
	Straight Track	Curved Track	Straight Track	Curved Track
Ties	0.0011 CV	0.0150 CV	0.0014 CV	0.0180 CV
Rails	0.0010 CV	0.0082 CV	0.0031 CV	0.0082 CV
O. T. M.	0.0008 CV	0.0038 CV	0.0008 CV	0.0040 CV
Ballast	0.0010 CV	0.0038 CV	0.0012 CV	0.0045 CV
Track Laying and Surfacing	0.0022 CV	0.0190 CV	0.0027 CV	0.0210 CV
Superintendence	0.0022 CV	0.0190 CV	0.0029 CV	0.0210 CV
Bridges, Trestles and Culverts	0.00067 CV	0.00067 CV	0.0009 CV	0.0009 CV

Note—In this table "C" varies with the several items and in each line of the table is the main line cost of the particular item of its tabular line for any particular road or division at an assumed or the usual average speed; and "V" is any change in speed under consideration in miles per hour. It must be remembered that the table is not good for changes in speed requiring or permitting a change in maintenance standards.

When cost is not separated into straight line and curved line costs the coefficient of CV is taken as the weighted average, the weights being the percentages of straight and curved line. Thus: If 60 per cent of the line is straight and 40 per cent is curved we have for passenger trains and ties

$(6 \times .0011 + 4 \times .0150) \div 10 = .00666$

and for freight trains and ties

$(6 \times .0014 + 4 \times .0180) \div 10 = .00804$

2. Cost of transportation will vary materially with variation in speed but it is not possible to determine in general a most economical speed expressed in miles per hour. The effect of variations of speed will depend on the characteristics of the division under consideration, on the wage system, on the character of the traffic, and on commercial considerations.

a. Since varying speed affects the load that can be hauled, the effect of speed cannot be considered apart from the train load. Provided there are no pusher grades, and that the wage system is a straight hourly pay system, traffic that does not require quick movement is moved most economically in maximum trains, defined to be those that can be handled at minimum practicable speed on the de facto ruling grade of the division. Under these conditions the most economical speed for the maximum train is the fastest speed that can be made safely over the division. If there are pusher grades or if the wage system calls for extra pay for all time over a standard day, then each division must be worked out for itself by experiment or as is outlined in pages 773-791 of the Proceedings of 1921.

b. Subject to the limiting effect of pusher grades and wage system it may be said that with a given weight of train the most economical speed is the fastest that can be made safely over a division.

c. The operating cost is a minimum under conditions "a" and "b" when the resulting speed is the one which permits the locomotive to be operated at the most economical rate of power production.

3. No data have been found that will throw any light on the relation of speed to cost of maintenance of equipment. It is believed that owing chiefly to the effect of impact and braking there will be a slight variation in the cost of maintenance of equipment with variations in speed that are not great enough to require change in character of equipment. When the speed becomes higher than that for which the locomotive is designed the cost is believed to increase rapidly with increase in speed.

Appendix C

METHODS FOR ANALYZING COSTS

LOUIS YAGER, *Chairman;*

W. G. ARN,	E. G. ALLEN,
MAURICE COBURN,	J. F. PRINGLE,
F. H. MCGUIGAN, JR.,	H. A. ROBERTS,

The Committee on Economics of Railroad Operation is interested in a great variety of transportation subjects in which various unit costs play very important parts. As the investigations of the Committee progress, many important problems will no doubt present themselves for economic comparisons, so that we feel that the assignment could not be properly completed until the scope of the Committee's investigations is more clearly outlined.

The Committee has already made some investigations and has others in progress in which the train-mile cost unit is an important consideration in the economic comparisons which are being studied, so that we have undertaken the study of analyzing freight and passenger train-mile costs as influenced by changes in locomotives, grades, operating methods, etc. This investigation is now in progress.

> Subject No. 7, "Begin the study of methods for determination of proper allowances for maintenance of way expenses, due to increased use and increased investment, collaborating with the Committee on Records and Accounts."

The studies and discussions to date have covered the field of previous investigations on this subject more or less closely related to rate litigations in various parts of the country. Detailed reference has been made to the more recent developments brought about by the activities of committees working on related phases of the subject for the Railroad Administration and Corporate Associations during and subsequent to Federal Control. It is agreed that some of the facts and conclusions developed in these investigations would be helpful in the study of our assignment, which we consider is intended to cover a broader and more comprehensive view of the maintenance field than that which prompted the investigations referred to.

The selection or development of a suitable transportation unit as a measure of "use" is considered the first step in the study. It was decided that the "use" unit should be related in as definite a way as possible to the two general classes of traffic which are in general distinguished by differences in speed of movement and total gross weight. These two factors in some manner directly influence the necessity for maintenance reparation. The following transportation units, train-mile, engine-mile, net ton-mile, gross ton-mile, car-miles, engine ton-miles and tractive power-mile, were studied and compared with the tentative requirements of the unit and were all rejected because they singly are not sufficiently inclusive to cover the variations in traffic.

It was tentatively concluded that some form of equated transportation units would have to be used to relate and measure the effects of passenger and freight service to maintenance requirements, until such time as maintenance and accounting science should develop a more accurate measure. The availability of the transportation units selected is given consideration. The necessity of having a maintenance "unit" related to a "use" unit was also developed.

The experience of the joint meeting with the Records and Accounts Committee indicated clearly the advisability of having the two Sub-Committees act essentially as a single committee in the study of the subject up to the point where appropriate units can be established so that the special function of the Records and Accounts Sub-Committee in developing the accounting and record phases of the subject may become active.

Appendix D

(6) THE ECONOMICAL OPERATION OF TRAINS AGAINST THE CURRENT OF TRAFFIC ON MULTIPLE TRACK RAILWAYS

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E. T. Howson,
R. T. Scholes,
L. S. Rose,
H. B. Grimshaw,
Sub-Committee.

A questionnaire was sent to the chief operating officers of 48 roads whom it was thought might able to present information on the subject assigned the Committee. A copy of the questionnaire is attached as Exhibit A.

From the roads addressed, the Committee was pleased to receive 33 replies, for which it desires to express its appreciation.

Eighteen roads replied they were not operating against the current, except in emergency. These were the

Atchison, Topeka & Santa Fe,
Boston & Albany,
Boston & Maine,
Bessemer & Lake Erie,
Canadian Pacific,
Central Railroad of New Jersey,
Chicago, Milwaukee & St. Paul,
Chicago & North Western,
Delaware, Lackawanna & Western,
Grand Trunk,
Lehigh Valley,
Michigan Central,
New York, Chicago & St. Louis,
Philadelphia & Reading,
Richmond, Fredericksburg, & Potomac,
Southern Pacific,
Toledo & Ohio Central,
Union Pacific.

One road declined to furnish the information for economic reasons.

Fourteen roads replied they were operating against the current of traffic in the regular course of business. The replies of the 14 covered over 4,000 miles of multiple tracks.

These roads are:

Atlantic Coast Line,
Baltimore & Ohio,
Chesapeake & Ohio,
Chicago, Burlington & Quincy,
Chicago & Eastern Illinois,
Chicago Great Western,
Chicago, Rock Island & Pacific,
Cleveland, Cincinnati, Chicago & St. Louis,
Erie,
Great Northern,
Hocking Valley,
Illinois Central,
New York, New Haven & Hartford,
Northern Pacific.

The replies in each individual case are so varied and so interesting that it is the thought that the experience of each road should be given to bring out more effectively the excellent results secured.

Atlantic Coast Line

This company operates a double track line against the current of traffic at one location for a distance of 1.1 miles. The average daily movement is 60 trains, consisting normally of 36 passenger and 19 freight trains. The maximum, however, is 70 trains per day, including 45 passenger and 25 freight trains. The average daily movement against the current is 30 trains. The normal movements are 18 passenger trains and 10 freight trains per day, but the maximum is 32 passenger trains and 13 freight trains.

The track is controlled by manual lock and block and by automatic block signals in both directions. All facing point switches are interlocked and the movements are made at any time of day with absolute safety. The extra cost for signaling approximated $29,900, but the building of a third track was avoided.

Baltimore & Ohio

The practice of operating trains against the current of traffic on multiple tracks without the use of train orders was first considered by the Baltimore & Ohio about 1911, when a third or center track was built on certain sections of the east end of the Cumberland Division. Towers were established at intervals of about five miles and also block signals installed to protect and permit trains to occupy the center track, moving either eastbound or westbound without train orders.

Prior to the construction of this center track and the installation of Automatic and Manual Block Signals, it was the practice of the Baltimore & Ohio to operate trains against the current of traffic on double or multiple tracks only under train orders.

The center track between the following points is operated under the Controlled Manual Block System, which admits traffic being moved in either direction by signal indications:

Miller to Hancock	8.40 miles
Sir Johns Run to Orleans Road	10.30 miles
Okonoko to Patterson Creek	11.70 miles
	30.40

while the eastbound freight track between Hancock and Sir Johns Run, 5.62 miles, is so equipped.

This method saves much time by eliminating the use of train orders and the capacity of the railroad is increased materially. In fact, a three-track railroad thus operated will handle almost the traffic of a four-track railroad and in this particular case the cost of constructing a fourth track was avoided.

The normal traffic is 24 passenger trains and 56 freight trains daily. The maximum is 30 passenger and 68 freight trains daily.

The movements against the current of traffic between the points mentioned below are normal:

Miller and Orleans Road	7 passenger and 50 freight trains
Okonoko and Patterson's Creek	14 passenger and 35 freight trains

Maximum.

Miller and Orleans Road	10 passenger and 60 freight trains
Okonoko and Patterson's Creek	16 passenger and 40 freight trains

the operation being from 12 to 24 miles against the current.

The term "Controlled Manual Block" infers that there is continuous track circuit throughout; the signals governing thereto are not only controlled by the track circuit, but are also under the control of a signalman. The principle on which all controlled manual block systems are based is that before a signal can be changed to indicate "Proceed," and a train is admitted into a block, the co-operation of two persons, one located at each end of the block, is necessary.

The Controlled Manual Block System and the Automatic Block System in use on the Baltimore & Ohio single track or multiple (third center) track operation is one hundred per cent safe. We have no record of accident caused by failure of the signal system on these sections of single or multiple tracks.

The extra cost of signals was about $2,800 per mile (1921 prices).

Chesapeake & Ohio

This road operates 22 miles of double track in this manner and will shortly add to this mileage 13.7 miles, making a total distance in one stretch of 35.7 miles; trains are controlled by a special lock and block system, supplemented by interlocked signals. "In addition to the section equipped as above, we operate trains against the current of traffic by train order, this latter practice being in effect on all double track and is done at no stated period, but when the occasion warrants."

The average daily traffic is 30 trains per day and the maximum daily traffic, 46 trains, namely, 14 passenger and 32 freight trains. The average daily movement against the current is 3 passenger and 3 freight trains, and the maximum 4 passenger and 7 freight trains.

The following is a description of the device in use for diverting traffic:

> "Each interlocking station is provided with an alternating current generator delivering current at 175 volts with a frequency of 100 cycles. The direction of traffic is controlled by traffic levers which must be unlocked from the remote station when the operator turns the generator by hand. The traffic levers cannot be unlocked while there is any part of a train in the block. In other words, when traffic has been diverted, the normal direction cannot be restored until the entire train has cleared the block and when the normal direction is set up, traffic cannot be diverted until all trains have cleared the block."
>
> "Our scheme of diverting traffic is different from any scheme used on other roads, and it is not endangered by crossed wires, grounds or lightning. We can, therefore, feel that we are diverting traffic with 100 per cent safety."

Chicago, Burlington & Quincy

The Burlington is a pioneer road in this method of moving trains; it has been handling traffic in this way for over 13 years and has had no accidents attributable to it.

It operates 989 miles of double track in this manner, as follows:

125 miles equipped with absolute permissive block signals.
430 miles equipped with straight automatic block signals, and
434 miles equipped with manual block signals.

Lines Equipped with A. P. B. Automatic Signals—125 Road Miles.

This double-track is signalled so that each track may be operated practically as single track. The average number of trains per day is:

Normal.	Passenger trains	12 each way.
	Freight trains	15 each way.
Maximum.	Passenger trains	15 each way.
	Freight trains	25 each way.

The average number of trains per day operated against the current of traffic is:

Normal.	Passenger trains	6 each way.
	Freight trains	6 each way.
Maximum.	Passenger trains	12 each way.
	Freight trains	12 each way.

For movement against the current of traffic trains are controlled by the A. P. B. automatic signal together with train orders. Trains are operated against the current of traffic for any distance to get around a proceeding train or trains, provided the track is not required for the movement of oposing trains. There are 15 facing-point crossovers in this territory, of which 66 per cent are interlocked.

This company has been operating against the current of traffic for over 13 years and has had no accidents attributable to this method of operation and states that it is its opinion that it is just as safe to operate against the current with proper precautions as it is to operate single track and that its experience of many years bears out this view.

The added cost of arranging automatic signals to cover movements in both directions amounts to approximately $1,000 per road mile. The company is of the opinion that operating against the current in this territory has obviated the necessity of constructing about 40 miles of third track at an estimated cost of $1,200,000.

With regard to the advantages of this method of operation, the company advises as follows:

> "It assists materially in getting trains over the road, reduces time of trains between terminals and penalty overtime to train crews, frequently avoids tying up trains account of the 16-hour law and in general results in more intensive and economical use of the tracks and other facilities."

Lines Equipped with Straight Automatic Signals—430 Road Miles.

No detailed information is given regarding traffic in this territory, due to the fact that this mileage covers a number of separate pieces of double track with varying conditions and traffic on each section. There are 39 facing point crossovers in this territory, of which 18 per cent are interlocked. Movements against the current of traffic are controlled by train order and block signals.

Lines Equipped with Manual Block Signals—434 Road Miles.

This mileage is made up of several different sections with varying conditions and traffic and for that reason no data is given as to number of trains operated and the number of trains run against the current. Movements against the current of traffic are handled by train order in combination with manual block signals. In this territory there are 37 facing-point crossovers, of which 16 per cent are interlocked.

In the month of September, 1921, a careful check was kept of the number of train movements against the current of traffic for a period of 15 days, with the following results:

	Total	*Per Day*
Passenger	803	53.5
Freight	627	41.8
Total	1430	95.3

These movements against the current took place on 989 miles of double track.

The chief operating officer of the C. B. & Q., in making reply to the questionnaire, states his views concisely as follows:

> "I do not think it is necessary to add anything further, except to say that the experience of this Company over a long period of years leads us to the view that the practice facilitates the movement of traffic materially and at the same time is safe if surrounded by proper precautions."

Chicago & Eastern Illinois

This road operates 167 miles of double track and 17 miles of triple track on which 37 passenger and 107 freight trains are operated normally each day, increasing at times to 39 passenger and 135 freight trains per day. The normal movement against the current of traffic is 4 passenger and 13 freight trains, but a maximum of 14 passenger and 31 freight trains have been moved in this manner.

All movements against the current of traffic are controlled by train order, automatic block signals providing protection in one direction only, which is with the current.

Trains are operated in this way at any time of day when necessary to facilitate a movement. All classes of trains are diverted to the opposing track, returning to the normal track when convenient, and these "Movements are as fully protected and as safe as in the operation of a single track which is not protected by automatic block signals." About 75 per cent of the facing point switches are interlocked.

Chicago Great Western

This company is using 50 miles of double track when it becomes necessary to facilitate the movement of fast freight trains using opposite track to pass a slow or drag freight train. The average daily movement of trains is 20 and the maximum 26, of which 2 are passenger trains. No distinction is made in the class of trains that are diverted. All facing-point switches in this territory are interlocked except two, and the automatic protection is in one direction only.

> "We have never experienced any trouble due to operating trains against the current of traffic in a limited way. As previously stated, we have only gone into the operation of trains in this manner in a very limited way and when we do find it necessary, every precaution is taken in the way of notifying track men, signal men, and agents where it is possible."
>
> "It is our opinion that unless the practice is a general one, so every one connected with the operation is familiar with it, there is a certain amount of hazard in connection with the operation."

Chicago, Rock Island & Pacific

The Rock Island makes use of 25 miles of its 309 miles of double track for movements opposing the current of traffic, and at times some five miles of third track. Also automatic signals are installed on these tracks for the protection of trains in the normal direction of traffic, and movements are controlled by train order and manual block when traffic is reversed. The movements are made at any time whenever "it is necessary to facilitate the movement of high class trains through districts in which switch engines are not employed."

> "The principal use of the opposing track is on the Illinois division, which is double track for 183 miles, on which there is a short mileage of third track. Opposing track double-track movement is used principally in the morning for inbound trains (i. e. toward Chicago) for a distance of approximately 25 miles on account of heavy inbound passenger and fast freight movements, and in the reverse direction during the evening rush hours."

Passenger trains only are diverted to the opposing track unless important freight trains will be unreasonably delayed, in which case they are also diverted. Diversion approximates 25 miles, but trains are usually returned at the first convenient point.

Facing point crossovers are not interlocked, but consideration is being given to making this installation. The reply states further, with regard to the safety or hazard of these movements—

> "In my opinion, trains can be safely operated against traffic only by confining such use in territory other than that used by switch engines, which are liable to be found using either track, and only under standard train rules on a track not fully protected with automatic signals. This should then not be done until all

train, engine, station, track and B&B employes clearly understand such use is liable to be made of these tracks and they may expect such use at any time and arrange protection accordingly. This I consider very necessary so engine and train men will understand that extra precaution must be used to avoid accidents and delays on account of track and bridges being impassable and necessary highway crossing and station protection being given to such movement. I feel this precaution is necessary whether this reverse movement is made under train order with manual block protection or automatic block signal and interlocked protection."

In answer to the question, "Has operating against the current relieved your company of necessity of building additional main tracks to handle its traffic?" the reply was—

"No, as cost of delays which would occur under present conditions, if the opposing track were not used, would not offset the cost of building additional track."

Cleveland, Cincinnati, Chicago & St. Louis

The "Big Four" began to utilize its double track by running trains against the current of traffic whenever the traffic warranted that method. It is operatinfg 539 miles of double track, all of which is operated against the current of traffic when required.

The average number of trains per day is as follows:

Division	*Normal Trains* *Passenger*	*Freight*	*Maximum Trains* *Passenger*	*Freight*
Cincinnati	18	28	20	34
Chicago	26	30	26	30
Cleveland-Indianapolis	27	20	30	24
Cairo	4	5	4	8
St. Louis	21	20	23	25

The average number of trains operated against the current of traffic daily is as follows:

Division	*Normal Trains* *Passenger*	*Freight*	*Maximum Trains* *Passenger*	*Freight*
Cincinnati	8	12	16	13
Chicago	3	7	8	12
Cleveland-Indianapolis	11	6	16	12
St. Louis	5	10	12	15

Movements against the current of traffic are controlled by train orders and the manual block system. Each track is signaled as a single track at all interlocking stations; home signals are placed upon bracket masts to give the same signal aspects for trains moving against the current of traffic as is provided for those running in the normal direction. On portions of the road where automatic signals have been installed, it is the practice to provide automatics with the current. Where grade signals are used, they are controlled electrically to the next interlocking station.

Trains are operated against the current a sufficient distance to get them around another train operating in the normal direction or to let a train operating in the normal direction pass. Double track crossovers on the St. Louis and Chicago divisions are all interlocked; those on the Cincinnati, Cleveland, Indianapolis and Cairo divisions are 80 per cent interlocked.

With regard to the general proposition of operating regularly against current of traffic, this road has stated its views as follows:

"It has been the practice of the Big Four to operate trains against the current of traffic ever since its double track has been built. We are, therefore, very strongly of the opinion that the operation of the double track in the reverse direction is as safe as the operation of any single track, if indeed it is not somewhat safer, because of the fact that particular attention is paid by all those interested in such operation."

On one division this method of operation has relieved this company for the present from the construction of six miles of third track and about six miles of passing track, costing approximately $600,000. It has also saved the construction of about 17 miles of third track and about 9 miles of sidings on the Chicago division.

Erie

The reply received from this road was so comprehensive and so much to the point in a study of this subject, that it is quoted in full, as follows:

"The Erie railroad operates trains against the current of traffic on double track 1,268 miles. Automatic block signals, interlocked towers, telephone train dispatching and message circuits are installed. At present we are operating daily on an average of 700 freight trains and 700 passenger trains. Of this total number an average of 145 trains per day are operated against the current of traffic, a few of which are passenger trains, the majority freight trains.

"When moving trains against the current of traffic we usually confine the movement between towers. A '31 train order' addressed to the operator and all east or westbound trains, as the case may be, is placed at the tower beyond the point where the train operating against the traffic is to cross back to its own track. Practically all reverse movements are provided for at interlocker towers having control of crossovers. The inferior train moving against the current of traffic receives a '19 order' after the '31 train order' has been placed and acknowledged.

"For a substantial number of years, ways and means have been provided which have facilitated the movement of traffic and the utilization of facilities. When installing automatic block signals, train order signals, consisting of a short arm attached to the pole 21 ft. below, the block signal was installed at advantageous points, which signal is operated by the tower operator under the direction of the train dispatcher. These train order signals have three indications:

"(a) Arm horizontal, red light; indication—stop on main track and report for instructions. It is forbidden to use a crossover at any point where a telephone train order signal is located, without permission.

"(b) Arm inclined 45 deg. above horizontal, yellow light; indication—take siding, and when clear of main track report for instructions. Passenger trains report before pulling in the siding.

"(c) Arm inclined 90 deg. above horizontal, green light; indication—proceed regardless of following superior trains (except as otherwise provided) until otherwise ordered. It is forbidden to accept the proceed indication if there is any known cause that will prevent making the usual running time. When a train accepts the proceed indication and for any cause is unable to make the usual running time it is required that the train be protected.

"In addition to the installation of these train order signals we also installed grade signals on certain grades, the arm of which is attached to the pole 6 ft. 6 in. below the signal arm, and designated by a letter 'G' on the face of a disc attached to the signal arm. The fixed position of this signal arm is 45 deg. above horizontal. These signals are located on heavy grades and authorize enginemen in charge of freight trains having 90 per cent and over the engine rating to pass the block signal in the stop position without first bringing their train to a full stop. All other trains and engines are required to observe block signals and rules pertaining thereto, and are not authorized by the grade signal to pass a block signal in the stop position without first bringing the train to a full stop. Enginemen authorized to accept this grade signal are required to proceed under full control, prepared to stop before meeting any obstruction within the block.

"We have discontinued the use of green classification flags and lights on all freight trains operating over complete double track divisions, and have also discontinued the use of white classification flags and lights on all extra trains except passenger extras on complete double track divisions.

"Trains in automatic double track territory are permitted to proceed with the current of traffic upon signal indication, which signal indication supersedes time table superiority. On some of our single track divisions we give the inferior train the right of track over the superior train to the regular time table meeting point, thus eliminating train orders and delays. Our motto is 'Keep trains moving.'"

Although not so stated in its reply, it is very evident that it considers this method of operation as quite essential to economical operation of double track.

Hocking Valley

The parallel tracks on this road are not operated at present strictly as double track, but it is planned to do so in time. It does, however, use one track for traffic in one direction and operates both ways on the other.

"The burden of our traffic falls upon the Toledo Division, 124 miles long, and to the end that this traffic may be handled economically and provide for further increase, we have already completed 47 miles of second track and plan to complete the entire distance.

"It is not our purpose when the second track has been completed to use the double track as double track is generally used; we contemplate the use of our second track for the handling of northbound tonnage trains only, confining north and southbound passenger trains and southbound freight trains to the other track. It is expected this method of operation will make possible a movement of tonnage trains over the division within the overtime limit and provide for the movement of the maximum number of trains. Our tonnage is now limited by passing track capacity (80 cars), to a maximum of 5,250 equated gross tons. We have been operating sections of second track (18 miles in length) south of Columbus on the above plan since 1903 with very satisfactory results."

Great Northern

The Great Northern operates trains against the current of traffic on 135 miles of double track; in fact, on all its double track, except between St. Paul and Minneapolis.

On the Mesaba division are 84 miles of double track equipped with A.P.B. signals which furnish protection for trains under normal current of traffic only. Normally there are 6 passenger and 36 freight trains daily, the freight trains at times increasing to 42. Two passenger and six freight trains are on the average run against the current daily and at times four passenger and 12 freight trains are operated in this manner. No distinction is made in the classes of trains diverted and there have been

> "no serious accidents due to the practice. Traffic from April to December on the Mesaba division consists principally of ore, coal, grain, flour and forest products. Ore trains run a distance of 103 miles and other trains 160 miles. Ore trains average 125 cars, 8,000 gross tons, pulled by a Mallet engine with a tractive power of 78,360 lb. Other through trains average 80 cars, 4,000 gross tons pulled by a Mikado engine with a tractive power of 60,930 lb. In a normal ore season we run 24 ore trains daily, and to avoid stopping these long, heavy trains, we take advantage of the double tracks and run passenger, time freight and light local trains around the heavy ore trains against the current of traffic on the opposite track. The ore trains make a round trip of 213 miles from dock to mine and return in less than 16 hours and must be kept moving continually to avoid tie-ups."

This method of operation is also followed on 51 miles of double track from Shelby Mountain to Browning Mine, and other shorter stretches on which the average daily traffic is 6 passenger and 8 freight trains and the maximum 12 passenger and 16 freight trains. Normally 1 passenger and 1 freight train are operated daily on the opposite track, but at times 4 passenger and 4 freight trains are operated daily against the current. Trains are moved by train order and there is no automatic protection, the movement being at any time through the day. The maximum distance moved is about 25 miles. No facing point switches are interlocked.

> "This method is generally considered absolutely safe. Train and enginemen thoroughly conversant with the rules should be as safe as when running normally. In this connection one hazard appears on a steep grade; for example, where one track is put up with a low elevation on curves in order that locomotives may handle the maximum train tonnage, the other track is put up with maximum elevation for high speed. In reversing the current of traffic, this is something the dispatcher, as well as the engineer controlling the train, must be thoroughly conversant with. So far since the inception of double track we have had no accident.
>
> "The advantages of this system are keeping live stock, fruit trains and perishable commodities moving, thereby eliminating claims; also saving in overtime of trains and enginemen, as well as better performance generally, especially when work trains are operated on double track."

Illinois Central

This company has 220 miles of double track over which the normal daily movement is 32 passenger trains and 35 freight trains, the latter increasing to as many as 50 trains daily and it operates from 2 to 6 trains daily against the current of traffic. The track is equipped with automatic block signals protecting in one direction only, and about 5 per cent of the facing-point switches are interlocked. The management has this to say about the safety of this method:

> "We have operated trains in this manner on the Illinois division for 10 years to my personal knowledge without an accident

or even hazard of accident, and while this reverse movement has not been extensive, I think it can be extended with perfect safety."

New York, New Haven & Hartford

The New Haven reverses the movement of traffic at two busy points on its line.

At Worcester, Mass., 1.9 miles of double track are operated in this manner. The traffic on these tracks is:

	Normal	*Maximum*
Passenger trains	30	42
Passenger drafts and light engines (N. Y., N. H. & H. R. R.)	32	44
Passenger drafts (B. & M. R. R.)	18	18
Switcher movements	6	6
Freight trains and interline transfers	22	26
	108	136

And the movements against the current of traffic are:

	Normal	*Maximum*
Passenger trains	8	9
Passenger drafts and light engines (N. Y., N. H. & H. R. R.)	8	10
Passenger drafts (B. & M. R. R.)	2	4
Switcher movements	3	4
Freight trains and interline transfers	4	7
	25	34

These movements are governed by "Manual Controlled Block" and trains are operated without distinction under the system at any time of day.

At New Haven there are 1.8 miles of four-track line, of which the two middle tracks are operated against the current of traffic at infrequent intervals, as the capacity of the tracks at present is not often exceeded. The traffic is:

	Normal			*Maximum*		
	E. B.	*W. B.*	*Total*	*E. B.*	*W. B.*	*Total*
Passenger trains	44	44	88	56	59	115
Freight trains	25	24	49	45	45	90
Light engines	60	60	120	63	64	127
	129	128	257	164	168	332

Traffic is controlled in both directions by manual control block with automatic intermediate signals.

> "In setting up the route for the manual control block the direction of automatic signal protection is established. All switches, both facing and trailing, are interlocked. The advantages gained by operating against the current of traffic are the flexibility which facilitates quick terminal movements at times of congestion."

Northern Pacific

The Northern Pacific has 635 miles in 17 stretches of varying lengths of double track on which trains are operated against the current of traffic; 507 miles are provided with A.B.S. for the normal movement; 17 miles have A.B.S. for protection in both directions on one track only and 111 miles have no automatic protection. On the section Livingston to Bozeman, 25 miles, staff protection is provided through a single track tunnel, also Stampede to Lester, 13 miles, staff protection is provided for 3 miles of single track, which includes the Cascade tunnel; the westbound track is provided here with A.B.S. protection in both directions.

The operation of the double track, Staples to Delworth, 106 miles, is typical. This is a 0.3 per cent line "on which we use one track as much as the other for reverse movements." The average daily traffic is 15 passenger and 18 freight trains; the maximum is 22 passenger and 24 freight trains. Normally 1 passenger and 2 freight trains are operated against the current, but this at times increases to 5 passenger and 10 freight trains against the current.

A.B.S. protection is provided for the normal movement. There are three facing point crossovers, but none are interlocked. As a rule, trains do not exceed a distance of 20 miles against the current, but the distance is not fixed.

Our experience as to the safety of this method of operation is "absolutely safe." "We have no records of any accidents attributable to this practice."

"We run trains against the current of traffic in order to expedite the movements of traffic, avoid delays and overtime." "Our business has not been heavy enough to suggest the necessity of additional main tracks. As business increases, we shall extend the practice and provide minor facilities to make it more effective, thus postponing the construction of additional main tracks."

While the foregoing has demonstrated thoroughly the feasibility of running trains against the current and the economies following that method in the vast majority of instances where tracks are being taxed to the limit, yet it is necessarily a subject for careful analysis and an interesting letter from the President of the Central Railroad of New Jersey is quoted here.

Central Railroad of New Jersey

"I have given thought to this letter, and have had some correspondence with one of your committee, and beg to advise that this questionnaire would not apply to our line.

"In the first place, we do not operate trains against the current of traffic on any of our tracks, except in cases of emergency, and during such periods of time we turn all of the current traffic over to an adjacent track, so that there is really no reverse movement, as trains are not operated against each other on such tracks during that period. Furthermore, the trains running against the ordinary current of traffic are operated during this period of emergency under train orders.

"This question, however, was very prominently before us several years ago, covering part of our four-track district. Through this territory, we have two eastbound and two westbound tracks. We made up charts at that time to determine whether it would be practicable to use three of the tracks as eastbound in the morning and three westbound in the evening.

"We found, however, that during this so-called rush-hour period, traffic in both directions was so heavy that it would not have been practicable to have occupied one of the trains in reverse movement.

"It must be borne in mind that our passenger service in the suburban district is of such a character that, made up of both express and local passenger trains, it is necessary for some of the through trains to run around other express trains that make certain stops. This means that a certain series of local trains, express trains with stops and through express trains all in westbound movement must have certain stretches of track that are kept open, where they are passed around the local or semi-express trains. To take a track away from them under such circumstances would necessarily impair the service seriously.

"Taking a certain period of time for our study, we found that 32 local passenger trains on track 3 were passed by 53 express or semi-express trains on track 1, and 22 on track 4 by 38 on track 2.

"At a certain station on our line, on July 22, 1917, a 24-hour period taken at random as covering daily heavy traffic, and at a point where there was about the average density of traffic within the territory considered, there were 101 eastbound and 102 westbound passenger trains, and 49 eastbound and 51 westbound freight trains, or an average of about 1 to each 4.75 minutes. Necessarily, with such heavy traffic in both directions, including both passenger and freight, there was no opportunity to consider successful operation by reversing traffic. It would necessitate practically suspending the traffic in one direction while operating against the current.

"We have studied some other lines where operations were being conducted against the current of traffic, and found that their situation was entirely different from ours, so that while it was practicable for them it was decidedly undesirable for us."

CONCLUSION

The replies to the questionnaire have demonstrated that trains can be operated successfully on multiple tracks against the current of traffic in the regular course of business, thereby facilitating their movement and effecting material economies without introducting additional hazards when proper precautions are taken; also in some cases avoiding or delaying the construction of additional main and passing tracks. The following is, therefore, recommended for insertion in the Manual:

Operation of trains against the current of traffic on multiple tracks should receive consideration with other methods whenever congestion, delay or overtime prompt investigation of means of facilitating the movement of traffic or increasing the capacity of a line.

Exhibit A

COMMITTEE 21—ECONOMICS OF RAILWAY OPERATION

Questionnaire

(Note—This questionnaire is not intended to apply to multiple tracks on which the current is reversed at certain hours of the day, *unless* trains are operated against the current in effect at the time the reverse movement is made.)

1. Does your Company operate tracks against the current of traffic on double or multiple tracks?
2. If so, what is the number of main line tracks used, i. e., 2, 3 or 4?
3. What is length in track miles used in this manner? Is all "double" or "multiple" track so operated or only in special locations? If the latter, please state special circumstances and between what stations.
4. What is the traffic on all tracks?
   Ans. (Average daily.)
   Normal—Pass. Trains. *Maximum*—Pass. Trains.
   Freight Trains. Freight Trains.
5. How many trains are operated against current of traffic?
   Ans. (Average daily.)
   Normal—Pass. Trains. *Maximum*—Pass. Trains.
   Freight Trains. Freight Trains.
6. Is the track controlled by
   Train Order?
   Manual Block?
   Automatic Block Signals?
   Combination of the Above?

   If by Automatic block signals, are they installed so as to secure protection in both directions the same as for single track?

   Or in one direction only giving rear protection only (straight automatic), as is ordinarily used on two or four tracks.
   Is control by staff?
7. Are trains operated against current at any time of day when same is necessary to facilitate movement of traffic?

   Or are they so operated only at stated periods of the day, i. e., morning, evening, night?
8. Are all classes of trains diverted to the opposing track as required, or are the passenger trains only diverted? Or is any distinction made?
9. *What is the maximum distance which you permit a train to run against the current in one movement?
10. Are all facing point crossovers interlocked? If not, what per cent are interlocked?
11. *What is your experience as to the safety in operating trains against current?

    (The Committee would appreciate a very full reply to this question, also your opinion in order to establish definitely the safety record or hazard under different methods of operation.)
12. What has been approximate extra cost of signals and other facilities made necessary by operation against current?
    Cost per road mile—$........
    Total Cost—$..........

13. Has operating against current relieved your company of necessity of building additional main tracks to handle its traffic?

    If so, how many miles of additional tracks has it saved and approximately what expenditure saved?

14. What in your opinion are the other advantages gained by operating against the current of traffic?

---

*(No. 9) The purpose of this question is to find out if trains are run against current of traffic any extensive distance, and if so how far, or are they returned to the normal track as soon as convenient to do it.

(No. 11) The Committee will appreciate a very full reply to this question, also your opinion in order to determine definitely the safety record or hazard under different methods of operation.

Appendix E

OPERATION OF ONE-ENGINE AND TWO-ENGINE TRAINS

In Comparison With Three-Engine Trains

By J. E. Teal

The report of the Committee on Economics of Railway Operation for 1920 included a paper on "The Effect of Speed of Trains on the Cost of Operation." This study was based on the operation of the Cumberland Division of the Baltimore & Ohio Railroad, which consists of two freight divisions. The west end freight division crosses the Alleghany Mountain range with maximum grades rated over two per cent, as described in Bulletin 234, Volume 22, February, 1921.

In March, 1921, the operation of this freight division was changed from three-engine trains eastbound and two-engine trains westbound to two-engine trains eastbound and one-engine trains westbound. Subsequent records of fuel consumption of these trains prompted the management to have a number of tests made in order to determine, as nearly as possible, the most economical method of operating over the mountain grades, particularly as to fuel consumption.

In conducting these tests it was assumed that the standard locomotive ratings, as previously determined for this division, were correct and the speed of freight trains between stops was practically the same in each test. The results, however, are of particular interest and show a much improved operation in getting the trains over the road by the lighter gross train load handled by the one-engine and two-engine trains.

Conclusions obtained from the tests follow:

(1) Assuming the same number of trains each way per day and filling out at Rinard to 5,000 adjusted tons on three-engine trains eastbound, the coal consumption between terminals on the 100 ton-mile basis is practically the same for the one-engine and two-engine trains as with the two-engine and three-engine trains.

(2) The Mallet engine on this division is more economical in coal consumption than the Mikado, where the Mikado is used as a helper on the 17 Mile Grade, westbound, between Piedmont and Altamont.

(3) The average miles per hour westbound is practically the same with the one-engine and two-engine trains.

(4) The average miles per hour eastbound is practically 7 per cent slower with the three-engine trains than with the two-engine trains.

(5) The time lost by stops eastbound with two-engine trains was 2 hours 24 minutes, while with the three-engine trains the time lost was 3 hours 39 minutes, showing one hour and 14 minutes longer, due mostly to cutting in the second helper on the three-engine trains, over what was lost where only one helper was used.

The following curves showing the tendency for slow freight trains to take longer time between terminals as the volume of traffic increases also shows the average crew time of one-engine and two-engine trains compared with two-engine and three-engine trains.

Since the one-engine and two-engine trains have been operated (March, 1921) the traffic has not been heavy enough to determine the economies of this operation with maximum traffic conditions. A study is now being made to determine the cost of this operation, taking all factors into consideration, as compared with the operation of two-engine and three-engine trains.

Place of Test

The West End of the Cumberland Division between Grafton and Keyser was selected for this test where these two methods of operation have been in vogue, and page 775 shows the general profile of the division.

Fuels Used

The fuel used was that usually used on the division and it was mostly from Consolidation 37 and Glendale Mines, all of the nut, pea and slack size.

Equipment Used

Baltimore & Ohio Mallet locomotive 7133, Class EL-3, was used as road engine on these tests, stoker fired on all runs.

The helper on the 17 Mile Grade was Baltimore & Ohio Mikado 4235 Class Q-1-c. It was used as a helper on the rear of the train.

The helpers on the other grades were Baltimore & Ohio Mallet 7023 Class EL-4 and Baltimore & Ohio Mallet 7049, Class EL-4. Where one helper was used it was put on the rear of the train. When the second helper was used it was cut in about forty cars from the front of the train.

Duration of Tests

Five round trips were run with one-Mallet-engine train westbound and two-Mallet-engine train eastbound. Then five round trips were run with two-engine train westbound, consisting of one Mallet and Mikado, and three-Mallet-engine train eastbound filling out at Rinard to 5,000 adjusted tons.

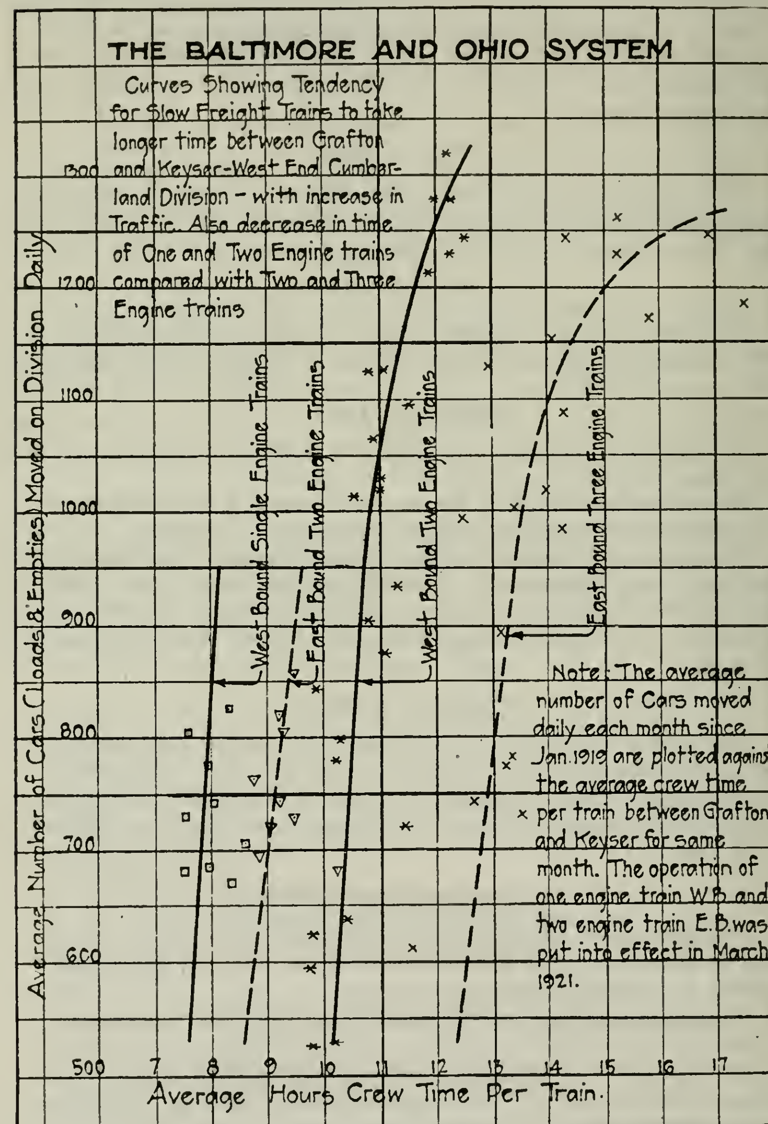
General Condition of Tests

The conditions under which the tests were run were as near the same as possible, so that the coal consumption under the two different methods of operating would be comparative.

The tonnage hauled and other data collected are shown on pages 771 to 774.

The Standard coal measuring box was built into the tender of each engine and all the coal used was measured through this box, before going to the stoker trough.

The depth of the fire on the grates was the same at the start and finish of each run as far as conditions would allow.


THE BALTIMORE AND OHIO SYSTEM
Curves Showing Tendency for Slow Freight Trains to take longer time between Grafton and Keyser-West End Cumberland Division - with increase in Traffic. Also decrease in time of One and Two Engine trains compared with Two and Three Engine trains
West Bound Single Engine Trains
East Bound Two Engine Trains
West Bound Two Engine Trains
East Bound Three Engine Trains
Note: The average number of Cars moved daily each month since Jan. 1919 are plotted against the average crew time per train between Grafton and Keyser for same month. The operation of one engine train W.B. and two engine train E.B. was put into effect in March 1921.
Average Number of Cars (Loads & Empties) Moved on Division Daily
1300
1200
1100
1000
900
800
700
600
500
7
8
9
10
11
12
13
14
15
16
17
Average Hours Crew Time Per Train.

In operating the three-engine train eastbound, it is necessary to maintain the Deer Park helper, using about 4,300 pounds of coal per trip. The coal consumed by the road engine is also increased by working the single engine harder from Grafton and Hardman and across the glades, all of which counterbalances any saving that the three-engine train might make.

The coal consumption per 100 ton-miles, assuming the same number of trains each way, with the one-engine and two-engine train operation, was 28.72 pounds west and 21.17 pounds east, or an average of 24.9 pounds.

Similarly, with the two-engine and three-engine train operation the coal consumption per 100 ton-miles was 27.59 pounds west and 21.84 pounds east, or an average of 24.71 pounds, showing no appreciable difference in the coal consumption between these two methods of operation.

Observations of Operation During the Test

On Tests 15, 19, 21 and 23 with three engines, trains were cut about thirty cars from the head end and advanced to Newburg, where the road engine took water. The two helpers brought the balance of the train forward. This movement required on an average of 3 minutes at Hardman and 14 minutes at Newburg.

On Test 17 the train was cut at Hardman, but instead of advancing as in the above tests, the helpers were cut in and the entire train advanced to Newburg, where the road engine took water. This movement required 15 minutes at Hardman and 14 minutes at Newburg or about 12 minutes longer than the first mentioned movement.

In making the fill-out at Rinard, it required about 40 minutes, including inspection of train.

At Bond it required approximately 20 minutes to inspect train, but on test 19 it required 1 hour and 20 minutes, part of the time due to broken knuckle in rear of train and then being held to wait for single-engine train to be inspected and allowed to leave ahead of the test train.

After making the second round trip, the engineer reported Engine 7133 needing flues cleaned and other repairs. This work was not done until the fourth round trip. It developed that there were thirteen large superheater flues stopped up and a number of smaller ones. On the last round trip, Test 23, the coal consumption was considerably better.

Description of Locomotive 7133.

Class	EL-3
Number	7133
Steam	Superheat
Stoker	Street
Weight on Drivers	459,400#
Weight on Front Truck	25,000#
Weight on Rear Truck	- - - - -
Weight of Total Locomotive	484,400#
Weight of Total Locomotive and Tender	693,400#
Wheel Base, Drivers	41' 2"
Wheel Base, Locomotive	50' 4"
Wheel Base, Locomotive and Tender	87' 5¾"
Valve Gear	Walschaert
Boiler Pressure	210#
Boiler Diameter	97-7/8"
Staying	Radial
Firebox	96" x 132-1/8"
Flues, Number 2-1/4"	269
Flues, Number 5-1/2"	48
Flues, Length	24'-0"
Heating Surface, Firebox*	341 sq. ft.
Heating Surface, 2-1/4" Flues	3790 sq. ft.
Heating Surface, 5-1/2" Flues	1653 sq. ft.
Heating Surface, Total	5784 sq. ft.
Heating Surface, Superheater	1415 sq. ft.
Grate Area	88.17 sq. ft.
Wheels, Driving, Dia.	58"
Wheels, Front Truck, Dia.	33"
Wheels, Rear Truck, Dia.	- - - - -
Tractive Effort, Simple	121,560#
Tractive Effort, Compound	101,300#
Ratio Weight on Drivers to T. E.	Simple 3.77 Compound 4.53
Ratio Total Weight to T. E.	Simple 3.98 Compound 4.78
Tender Wheels, No. Tender	8
Tender Wheels, Dia	33"
Water Capacity	12,000 gals.
Coal Capacity	20 tons
Nozzle Diameter	7"
Bridge	Yes
Arch	Yes, solid.
Diameter Piston Rods	4-1/4"
Diameter L. P. Cylinders	41"
Diameter H. P. Cylinders	26"
Stroke	32"

* Includes combustion chamber.

THE BALTIMORE AND OHIO SYSTEM

TEST BUREAU

BALTIMORE, MD.

J. H. ONDERDONK.

TESTS ON WEST END CUMBERLAND DIV.

SUPERHEATER, STOKER FIRED, WITH N. P. & S. GAS COAL

WEST BOUND RUNS 4 TON ADJUSTMENT

1 Test No.	1	4	6	8	10	Average
2 Eng. No.	7133	7133	7133	7133	7133	
3 Kind of Coal	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	
4 Coal from Mine	CONSOL.#37	CONSOL.#37	CENTURY#2	CONSOL.#37	CONSOL.#37	
5 Kind of Firing	STOKER	STOKER	STOKER	STOKER	STOKER	
6 Date of Test	6-8-21	6-13-21	6-15-21	6-17-21	6-20-21	
7 Engineer	C.W. WOLF	C.W. WOLF	C.W. WOLF	C.W. WOLF	C.W. WOLF	
8 Fireman	J.Z. GARLITZ	J.Z. GARLITZ	J.Z. GARLITZ	J.Z. GARLITZ	J.Z. GARLITZ	
9 Train No.	EX.W.7133	EX.W.7133	EX.W.7133	EX.W.7133	EX.W.7133	
10 No. Cars	46	46	46	46	46	46
11 No. Loads	0	0	0	0	0	0
12 Actual Tonnage	1012	1012	1012	1012	1012	1012
13 Adjusted Tonnage	1196	1196	1196	1196	1196	1196
14 Time on Div.	6H.-23M.	5H.-21M.	5H.-39M.	5H.-53M.	5H.-32M.	5H.-45M.
15 Time in motion	4H.-54M.	4H.-46M.	4H.-51M.	4H.-45M.	4H.-36M.	4H.-46M.
16 Time Lost by Stops	1H.-29M.	0H.-35M.	0H.-48M.	1H.-08M.	0H.-56M.	0H.-59M.
17 Time Between Call and Lv.	0H.-49M.	0H.-44M.	1H.-00M.	0H.-52M.	0H.-48M.	0H.-51M.
18 Average Running Speed	16.1 M.P.H.	16.5 M.P.H.	16.2 M.P.H.	16.6 M.P.H.	17.1 M.P.H.	16.5 M.P.H.
19 Weather						
20 Temperature Max. and Min.						
21 Wind						
22 Max. Boiler Pressure						
23 Min. Boiler Pressure						
24 Avg. Boiler Pressure	194.7	188.2	194.4	196.8	197.7	194.4
25 No. Times Fire Cleaned	0	0	0	0	0	0
26 No. Times Fire Raked	4	1	2	1	1	1.8
27 No. Times Grate Shaken	1	1	0	1	1	0.8
28 Times Ash Pan Cleaned	0	0	0	0	0	0
29 No. Times Eng. Popped	2	4	8	12	5	6.2
30 No. Times Eng. Slipped						
31 Av. Throttle						
32 Av. Reverse Lever						
33 Weight of Coal Used	20880	22760	23760	23220	23760	114380*
34 Weight of Water Used						
35 Temp. of Water						
36 Pounds Water per Lb. of Coal						
37 Temp. of Steam						
38 Lbs. Water per Lb. Coal, from and at 212 F.						
39 Pounds Coal per Mile	265.3	289.2	301.9	295.0	301.9	290.7
40 Pounds Coal per 100 T. M.	26.2	28.6	29.8	29.2	29.8	28.72
41 Av. D. B. Pull						
42 Pounds Res. per Ton on Level						
43 Av. Horse Power						
44 No. Scoops Hand Fired						
45 Actual Ton Miles	79644.4	79644.4	79644.4	79644.4	79644.4	79644.4
46 Ton Adjustment						
47 Lbs. Coal per 1000 Lb. D. B. P. Mile						
48 Lbs. Coal per H. P. Hour						
49 Lbs. Coal per Sq. Ft. Grate per Hr.	45.76	53.08	54.51	53.42	56.86	52.73
50 Efficiency						
51 Arch						
52 Helpers						
53 Mileage	78.7	78.7	78.7	78.7	78.7	78.7

NOTE—* Indicates Total

THE BALTIMORE AND OHIO SYSTEM

TEST BUREAU

BALTIMORE, MD.

J. H. ONDERDONK.

TESTS O.. WEST END CUMBERLAND DIV.

SUPERHEATER, STOKER FIRED, WITH N. P. & S. GAS COAL

EAST BOUND RUNS 4 TON ADJUSTMENT

1 Test No.	3	5	7	9	11	Average
2 Eng. No.	7133	7133	7133	7133	7133	
3 Kind of Coal	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	
4 Coal from Mine	GLENDALE	CONSOL. #37	CONSOL. #37 GLENDALE	GLENDALE	GLENDALE	
5 Kind of Firing	STOKER	STOKER	STOKER	STOKER	STOKER	
6 Date of Test	6-11-21	6-14-21	6-16-21	6-18-21	6-21-21	
7 Engineer	C.W.WOLF	C.W.WOLF	C.W.WOLF.	C.W.WOLF	C.W.WOLF	
8 Fireman	J.Z.GARLITZ	J.Z.GARLITZ	J.Z.GARLITZ	J.Z.GARLITZ	J.Z.GARLITZ	
9 Train No.	Ex.E.7133	Ex.E.7133	Ex.E.7133	Ex.E.7133	Ex.E.7133	
10 No. Cars	30	30	31	31	30	30.4
11 No. Loads	30	30	31	31	30	30.4
12 Actual Tonnage	2310	2310	2387	2384	2393	2356.8
13 Adjusted Tonnage	2450	2430	2511	2508	2513	2482.4
14 Time on Div.	9H-45M.	7H.-49M.	6H.-50M.	9H.-49M.	6H.-31M	8H.-09M.
15 Time in motion	5H.-49M.	5H.-54M.	5H.-25M.	6H.-04M.	5H.-35M.	5H.-45M
16 Time Lost by Stops	3H.-56M.	1H.-55M.	1H-25M.	3H.-45M.	0H.-56M.	2H.-24M
17 Time Between Call and Lv.	0H.-32M.	0H-37M.	0H-36M.	0H.-34M.	0H.-35M.	0H.-35M
18 Average Running Speed	13.5 M.P.H.	13.4 M.P.H.	14.5 M.P.H.	12.9 M.P.H.	14.1 M.P.H.	13.7 M.P.H
19 Weather						
20 Temperature Max. and Min.						
21 Wind						
22 Max. Boiler Pressure						
23 Min. Boiler Pressure						
24 Avg. Boiler Pressure	199.7	195.3	199.7	195.9	194.1	196.9
25 No. Times Fire Cleaned	0	0	0	0	0	0
26 No. Times Fire Raked	3	1	2	3	2	2.2
27 No. Times Grate Shaken	1	1	1	2	1	1.2
28 Times Ash Pan Cleaned	0	0	0	0	0	0
29 No. Times Eng. Popped	6	4	2	8	7	5.4
30 No. Times Eng. Slipped						
31 Av. Throttle						
32 Av. Reverse Lever						
33 Weight of Coal Used	24480 / 15510	22760 / 14605	25920 / 14100	22180 / 13950	23780 / 13950	196415 *
34 Weight of Water Used						
35 Temp. of Water						
36 Pounds Water per Lb. of Coal						
37 Temp. of Steam						
38 Lbs. Water per Lb. Coal, from and at 212 F						
39 Pounds Coal per Mile	311.5 / 291.5	383.3 / 353.2	373.4 / 313.4	345.4 / 311.7	301.7 / 311.7	315.5 / 337.3
40 Pounds Coal per 100 T. M. Road Eng. / Helper	22.0	20.7	21.3	21.9	20.0	21.17
41 Av. D. B. Pull						
42 Pounds Res. per Ton on Level						
43 Av. Horse Power						
44 No. Scoops Hand Fired						
45 Actual Ton Miles	181797.0	181797.0	187856.9	187620.8	188329.1	185480.2
46 Ton Adjustment						
47 Lbs. Coal per 1000 Lb. D. B. P. Mile						
48 Lbs. Coal per H. P. Hour						
49 Lbs. Coal per Sq. Ft. Grate per Hr.	41.36 / 60.84	40.38 / 69.32	52.01 / 72.10	45.53 / 65.01	49.85 / 72.09	45.47 / 68.67
50 Efficiency						
51 Arch						
52 Helpers	7049	7049	7049	7049	7049	
53 Mileage	78.7 / 13.6	78.7 / 13.6	78.7 / 13.6	78.7 / 19.0	78.7 / 13.6	78.7 / 13.6

*Note * Indicates Total.*

THE BALTIMORE AND OHIO SYSTEM

TEST BUREAU

BALTIMORE, MD.

J. H. ONDERDONK.

TESTS ON WEST END CUMBERLAND DIV.

SUPERHEATER, STOKER FIRED, WITH N.P.&S GAS COAL

WEST BOUND RUNS 4 TON ADJUSTMENT

1 Test No.	14	16	18	20	22	Average
2 Eng. No.	7133	7133	7133	7133	7133	
3 Kind of Coal	N.P.&S.GAS	N.P.&S.GAS	N.P.&S GAS	N.P.&S GAS	N.P.&S.GAS	
4 Coal from Mine	CONSOL #37	CONSOL #37	CONSOL #37	CONSOL #37	CONSOL #37	
5 Kind of Firing	STOKER	STOKER	STOKER	STOKER	STOKER	
6 Date of Test	7-5-21	7-7-21	7-9-21	7-12-21	7-14-21	
7 Engineer	J.W.FROMHART	G.W WOLF	G.W WOLF	G.W.WOLF	G.W.WOLF.	
8 Fireman	A.L.STANAGEN	E.C.DEMOSS	E.C.DEMOSS	E.C.DEMOSS	E.C.DEMOSS	
9 Train No	Ex.W. 7133	Ex.W 7133	Ex W. 7133	Ex.W. 7133	Ex W. 7133	
10 No. Cars	75	77	75	75	75	75.4
11 No. Loads	0	0	0	0	0	0
12 Actual Tonnage	1500	1492	1500	1500	1500	1498.4
13 Adjusted Tonnage	1800	1800	1800	1800	1800	1800.0
14 Time on Div.	6H.-29M.	6H.-35M	5H.-38M.	7H.-28M.	6H.-30M.	6H.-32M.
15 Time in motion	4H.-56M.	4H.-40M.	4H.-45M.	5H-21M.	4H-45M.	4H.-53M.
16 Time Lost by Stops	1H.-33M.	1H.-55M.	0H.-53M.	2H.-07M.	1H.-45M.	1H.-39M.
17 Time Between Call and Lv.	1H.-48M.	1H.-00M.	0H.-42M.	1H.-25M	0H.-45M.	1H.-08M.
18 Average Running Speed	16.0 M.P.H.	16.9 M.P.H.	16.6 M.P.H	14.7 M.P.H.	16.6 M.P.H	16.2 M.P.H.
19 Weather						
20 Temperature Max. and Min.						
21 Wind						
22 Max. Boiler Pressure						
23 Min. Boiler Pressure						
24 Avg. Boiler Pressure	190.3	195.9	200.6	199.4	210.0	199.2
25 No. Times Fire Cleaned	0	0	0	0	0	0
26 No. Times Fire Raked	0	0	0	5	0	1
27 No. Times Grate Shaken	0	0	0	0	0	0
28 Times Ash Pan Cleaned	0	0	0	0	0	0
29 No. Times Eng. Popped	1	0	0	0	0	0.2
30 No. Times Eng. Slipped						
31 Av. Throttle						
32 Av. Reverse Lever						
33 Weight of Coal Used - Road Engine	23760	21600	23040	26280	19980	114660*
34 " " " " Helper 4235-17 Mi. Grade	6740	7020	7020	6480	7200	34460*
35 " " " " " " Drifting	540	540	540	540	540	2700*
36 " " " " " " Cheat River Grade	2520	2070	1800	1440	2160	9990*
37 " " " " " " Drifting	180	180	180	180	180	900*
38 " " " " Total	33740	31410	32580	34920	30060	162710*
39 Pounds Coal per Mile 7133 4235	301.9 479.8	274.5 454.1	292.8 441.7	334.0 400.0	253.9 466.6	291.4 448.4
40 Pounds Coal per 100 T. M. R	28.6	26.7	27.6	29.5	25.4	27.59
41 Av. D. B. Pull						
42 Pounds Res. per Ton on Level						
43 Av. Horse Power						
44 No. Scoops Hand Fired						
45 Actual Ton Miles	118050.0	117420.4	118050.0	118050.0	118050.0	117924.1
46 Ton Adjustment						
47 Lbs. Coal per 1000 Lb. D. B. P. Mile						
48 Lbs. Coal per H. P. Hour						
49 Lbs. Coal per Sq. Ft. Grate per Hr. 7133 4235	51.98 79.81	48.96 89.26	53.40 76.84	52.34 55.06	44.57 88.32	50.25 77.86
50 Efficiency						
51 Arch						
52 Helpers	4235	4235	4235	4235	4235	
53 Mileage 7133 4235	78.7 20.8	78.7 21.6	78.7 21.6	78.7 21.6	78.7 21.6	78.7 21.4

NOTE:- * Indicates Total

THE BALTIMORE AND OHIO SYSTEM

TEST BUREAU

BALTIMORE, MD.

J. H. ONDERDONK.

TESTS ON WEST END CUMBERLAND DIV.

SUPERHEATER STOKER FIRED, WITH N.P.&S. GAS COAL

EAST BOUND RUNS 4 TON ADJUSTMENT

1 Test No.	15	17	19	21	23	Average
2 Eng. No.	7133	7133	7133	7133	7133	
3 Kind of Coal	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	N.P.&S.GAS	
4 Coal from Mine	GLENDALE	GLENDALE CONSOL #37	GLENDALE CONSOL #37	GLENDALE CONSOL #37	CONSOL #37	
5 Kind of Firing	STOKER	STOKER	STOKER	STOKER	STOKER	
6 Date of Test	7-6-21	7-8-21	7-11-21	7-13-21	7-15-21	
7 Engineer	J.W. FROMHART	C.W. WOLF	C.W. WOLF	C.W. WOLF	C.W. WOLF	
8 Fireman	G.L. STANAGEN	E.C. DEMOSS	E.C. DEMOSS	E.C. DEMOSS	E.C. DEMOSS	
9 Train No.	Ex.E.7133	Ex E.7133	Ex E 7133	Ex.E.7133	Ex E.7133	
10 No. Cars	48-67	47-64	47-63	47-63	46-63	47-64
11 No. Loads	48-67	47-64	47-63	47-63	46-63	47-64
12 Actual Tonnage	3566-4820	3529-4805	3525-4811	3299-4554	3199-4295	3424-4657
13 Adjusted Tonnage	3758-5088	3717-5061	3723-5063	3487-4806	3383-4547	3614-4913
14 Time on Div.	9H-30M.	9H-16M.	12H-15M.	8H-53M.	9H-21M.	9H-51M.
15 Time in motion	6H-18M.	6H-01M.	6H-28M.	6H-14M.	5H-57M.	6H-12M.
16 Time Lost by Stops	3H-12M.	3H-15M.	5H-45M.	2H-39M.	3H-24M.	3H-39M.
17 Time Between Call and Lv.	0H-45M.	0H-19M.	0H-45M.	0H-46M.	0H-41M.	0H-39M.
18 Average Running Speed	12.5 M.P.H.	13.1 M.P.H.	12.2 M.P.H.	12.6 M.P.H.	13.4 M.P.H.	12.7 M.P.H.
19 Weather						
20 Temperature Max. and Min.						
21 Wind						
22 Max. Boiler Pressure						
23 Min. Boiler Pressure						
24 Avg. Boiler Pressure	201.2	202.4	203.5	202.1	204.8	202.8
25 No. Times Fire Cleaned	0	0	0	0	0	0
26 No. Times Fire Raked	0	0	0	0	0	0
27 No. Times Grate Shaken	0	0	0	0	0	0
28 Times Ash Pan Cleaned	0	0	0	0	0	0
29 Weight of Coal Used-Road Engine	30960	26270	30600	29520	25920	143270*
30 " " " " 2 Helpers Hardman to West End	8528	9300	10463	9661	10075	48027*
31 " " " " " Drifting	2325	1550	1550	1550	1550	8525*
32 " " " " 2 Helpers M.&K. Jct. to Terra Alta	14725	15500	14725	13950	15500	74400*
33 " " " " " Drifting	1550	2325	1550	2325	2325	10075*
34 " " " " 1 Helper-Deer Park Grade	3100	2325	4263	3875	3875	17438*
35 " " " " " Drifting	775	775	1163	775	775	4263*
36 1/5 Coal-Rinard Turn Around	16922	16867	17050	16654	16533	84026*
37 " -Running Light-Rinard to Grafton	1880	1880	1880	1880	1880	9400*
38 Total Weight of Coal Used	80765	76792	83244	80190	78433	399424*
39 Pounds Coal per Mile-Road Eng.	393.4	333.8	388.8	375.1	329.4	364.1
40 Pounds Coal per 100 T. M.	21.3	20.3	22.0	22.4	23.2	21.84
41 Av. D. B. Pull						
42 Pounds Res. per Ton on Level						
43 Av. Horse Power						
44 No. Scoops Hand Fired						
45 Actual Ton Miles	379334.0	378153.5	378625.7	358399.8	338016.5	366505.9
46 Ton Adjustment						
47 Lbs. Coal per 1000 Lb. D. B. P. Mile						
48 Lbs. Coal per H. P. Hour						
49 Lbs. Coal per Sq. Ft. Grate per Hr.-Road Eng.	60.06	44.90	46.08	50.12	44.55	49.14
50 Efficiency						
51 Arch						
52 Helpers	7023-7049	7023-7049	7023-7049	7023-7049	7023-7049	
53 Mileage	78.7	78.7	78.7	78.7	78.7	78.7

NOTE-*Indicates Total

THE BALTIMORE AND OHIO SYSTEM

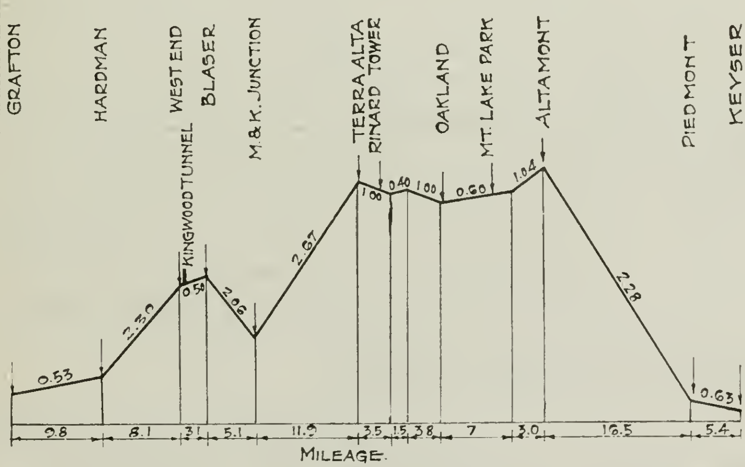
General Description of Division

The profile of the West End Cumberland Division, on which the tests were run, is given below, showing the distances between the main points and the maximum grades encountered on the various hills.

The maximum curvatures encountered between the main stations are as follows:-

Between	Grafton and Hardman	8°-32'
"	Hardman and West End	12°-31'
"	West End and Blaser	8°-30'
"	Blaser and M.&K. Junction	12°-00'
"	M.&K. Junction and Terra Alta	12°-16'
"	Terra Alta and Mt. Lake Park	9°-33'
"	Mt. Lake Park and Altamont	5°-49'
"	Altamont and Piedmont	12°-00'
"	Piedmont and Keyser	4°-30'

East Bound →



Condensed Profile
West End Cumberland Division

Summary of Results

	WEST BOUND		EAST BOUND	
	1 Eng. Trn.	2 Eng. Trn.	2 Eng. Trn.	3 Eng. Trn.
Road Engine No.	7133	7133	7133	7133
No. Cars	46	75.4	30.4	47-64
No. Loads	----	----	30.4	47-64
Actual Tonnage	1012	1498.4	2356.6	3424-4657
Adjusted	1196	1800.0	2482.4	3614-4913
Time on Division	5-H,45-M	6-H,32-M	8-H,09-M	9-H,51-M
Time in Motion	4-H,46-M	4-H,53-M	5-H,45-M	6-H,12-M
Time lost by Stops	0-H,59-M	1-H,39-M	2-H,24-M	3-H,39-M
Time between calling and leaving	0-H,51-M	1-H,08-M	0-H,35-M	0-H,39-M
Ave. Speed M.P.H.	16.6	16.2	13.7	12.7
Ave. Boiler Pressure	194.4	199.2	196.9	202.8
Total Weight of Coal used 5 Rd. Trips	114,380	162,710	196,415	399,424
Pounds Coal per 100 ton miles.	28.72	27.69	21.17	21.34

Information on Grades

The following tables show the average speed on the 17 Mile Grade and Cranberry Grade.

WEST BOUND

	WEST VIRGINIA JUNCTION TO ALTAMONT											
Distance 15.7 M	Single Engine Trains						Two Engine Trains					
Test No.	1	4	6	8	10	Ave.	14	16	18	20	22	Ave.
No. of Cars (Mty)	46	46	46	46	46	46	75	77	75	75	75	75.4
Actual Tonnage	1012	1012	1012	1012	1012	1012	1500	1492	1500	1500	1500	1498.4
Adjusted Tonnage	1196	1196	1196	1196	1196	1196	1800	1800	1800	1800	1800	1800.0
Running Time	1'25"	1'16"	1'18"	1'18"	1'16"	1'19"	1'31"	1'09"	1'17"	1'38"	1'12"	1'21"
Ave. Running Speed	11.1	12.4	12.0	12.0	12.4	12.0	10.5	15.4	12.0	9.8	13.1	12.2

Notes- On Test #16 did not stop. This train made up of box cars
On Test #20 stopped at Bloomington and Bond.
Table #1 Start and Finish - Running. Test 3 delay 2 hrs. 1 mn. Stoker failure Eng. 7049
Table #2 Start - made from dead stop. Finish - Running.

EAST BOUND

	M. & K. JUNCTION TO TERRA ALTA											
Distance 11.9 M	Two Engine Trains						Three Engine Trains					
Test No.	3	5	7	9	111	Ave.	15	17	19	21	23	Ave.
No. of Cars (Loads)	30	30	31	31	30	30.4	48	47	47	47	46	47
Actual Tonnage	2310	2310	2387	2384	2393	2356.8	3566	3529	3525	3522	3199	3468.2
Adjusted Tonnage	2450	2430	2511	2508	2513	2482.4	3756	3717	3723	3710	3383	3578.2
Running Time	1'14"	1'03"	1'01"	1'06"	1'03"	1'05"	1'15"	1'12"	1'15"	1'19"	1'05"	1'13"
Ave. Running speed	9.7	11.2	11.9	11.8	11.2	11.2	9.8	9.9	9.8	9.2	10.8	9.9

REPORT OF COMMITTEE VI—ON BUILDINGS

W. T. Dorrance, *Chairman;*
G. A. Belden,
Eli Christiansen,
D. R. Collin,
Arthur Crable,
W. L. Darden,
F. M. Davison,
J. B. Gaut,
A. M. Griffin,
J. W. Orrock, *Vice-Chairman;*
A. C. Irwin,
F. R. Judd,
G. A. Mitchell,
Hugo Filippi,
R. V. Reamer,
C. W. Richey,
G. A. Rodman,
Committee.

To the American Railway Engineering Association:

The Committee on Buildings submits the following report of its work for the past year.

(1) Manual

Complete rearrangement of the subject-matter was made for publication in the new Manual. The Committee at this time have no changes or revisions to recommend.

(2) Specifications for Buildings for Railway Purposes

The preparation of specifications, begun last year, was continued along similar lines. The Committee had hoped to present at this time specifications covering all the subjects outlined. It was found impracticable to entirely complete these, but seven (7) subjects have been covered, as included in Appendix A of this report.

It is hoped during the coming year to present an additional report covering subjects left undone so that at the next Convention we may offer the entire group of specifications for adoption by the Convention.

It would be helpful to the Committee to receive suggestions and advice with regard to the specifications presented and we earnestly urge upon all members that this be given consideration so that when presented for adoption, we may feel that the different points have been carefully considered.

(3) Ice Houses and Icing Stations

The Committee offers as information, the report of its Sub-Committee given in Appendix B of this report.

(4) Floors for Railway Buildings

The Committee offers as information, report of its Sub-Committee given in Appendix C of this report.

(5) Freight House Design

The Committee found that there was very little available data with regard to the elements entering into design of freight houses and appointed one of its members, Mr. Hugo Filippi, to study this subject. The result of his study and investigation is given in Appendix D of this report.

A

(7) Standardization

During the year the Committee was instructed to take up the question of standardization of various articles. The Committee is not ready to make any definite recommendations, but presents as a progress report the work of its Sub-Committee given in Appendix E of this report.

(6) Outline of Work

The Committee recommends that, in addition to continuing the uncompleted assignments, the following subjects be assigned for investigation and report:

1. Ventilation of Buildings.
2. System for Numbering Railroad Buildings.
3. Design and Specifications for Different Types of Chimneys or Stacks.
4. Economical Types of Ornamental Roof Coverings for Passenger Stations.

CONCLUSIONS

The result of this year's work is presented as information and the Committee has no conclusions to offer to the Convention at this time.

Respectfully submitted,

The Committee on Buildings,

W. T. Dorrance, *Chairman.*

Appendix A

SPECIFICATIONS FOR RAILWAY BUILDINGS

J. W. Orrock, *Chairman;*
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The Committee presents for discussion the following Specifications.

SPECIFICATIONS FOR RAILWAY BUILDINGS

SECTION 9

Painting and Glazing

1. General.

Under the heading of "Painting" shall be included the following:

(a) Painting and finishing exterior and interior woodwork.
(b) Painting structural steel and iron work and all ornamental iron work.
(c) Painting exposed sheet metal work and rain conductors.
(d) Painting plastered surfaces.
(e) Painting brick and concrete wall surfaces and concrete ceilings.
(g) Painting and lettering signs, and lettering on doors, etc.
(h) Painting radiators, piping, etc.

Under the heading of "glazing" shall be included the furnishing and setting of glass in window, door, transom and ceiling sash, including metal sash, and furnishing and setting glass in skylights and marquises.

The Contractor shall furnish all labor, tools, equipment and everything necessary to complete the painting and glazing required. The equipment shall include all ladders, scaffolding or staging necessary to execute the work. No ladders, scaffolding or staging shall be placed where they will interfere with the safe operation of trains and in buildings partially or wholly occupied by the Company and in which painting is in progress, the Contractor shall take proper precautions to protect the public and employees of the Company from any and all damage from his operations.

2. Materials.

Paints, stains and varnishes shall be of a brand acceptable to and approved by the Engineer, and shall be delivered at the site in the original unbroken factory containers with labels intact. Paints shall be furnished in ready mixed form and shall be thinned only in accordance with the directions furnished by the manufacturers or as directed by the Engineer. Thinners shall be pure raw linseed oil or pure spirits of turpentine or a mixture of these two. Benzine, naphtha, gasoline or coal oil will not be allowed on the work or mixed with any of the materials used. Paints not otherwise specified may consist of pure raw linseed oil and white lead, properly tinted, each coat to be of slightly different shade, and the final coat to be of a shade and color approved by the Engineer.

Enamels shall consist of long oil, easy flowing, durable varnishes, that remain white, set dust free in six hours and hard in twelve hours, capable of being rubbed in two days.

Interior wood stains shall be of pure color, with linseed oil vehicle, permanent as to shade, sharp and clear in tone and capable of deeply penetrating the surface.

Shingle stains shall be of a pure color with creosote or other wood preservative as the vehicle, and shall be permanent as to shade and deeply penetrating.

Varnishes shall be oil and gum goods that will withstand hard use and not show white or dust from the surface.

3. Application of Paint.

Only careful and skilled workmen shall be employed and special care shall be taken to avoid spattering, or setting of pots where they will disfigure the finished work. Canvas and building papers shall be spread where directed by the Engineer in order to protect finished or unfinished work. Paint shall be kept thoroughly stirred while being applied.

4. Preparing the Surface.

Woodwork shall be carefully hand-smoothed and nail holes, cracks or other imperfections of the surface shall be puttied after the priming coat is applied.

Paints, fillers, stains or varnishes must not be applied to wet, frosty or rusty surfaces, to wood showing sand paper marks or to surfaces not properly prepared. Knots, pitch pockets or sap shall be completely coated with first quality pure orange shellac before any paint is applied. Castings shall be filled with an iron filler and smoothed with emery and all imperfections treated and faced before applying the first coat of paint.

Brick, concrete, and plastered surfaces shall be absolutely dry before any paint is applied. Such surfaces shall be thoroughly cleaned with brushes to remove any loose material. Concrete floor surfaces shall be absolutely dry and free from oil, grease, dust, loose particles or any foreign matter that will in any way interfere with the most perfect penetration of the paint into the pores of the surface.

5. Time for Drying.

Each coat of paint shall be given sufficient time to dry hard before the next coat is applied.

6. Weather and Temperature.

Exterior painting shall not be done during damp or freezing weather, and all fresh work shall be protected from damage. For interior work the temperature shall not be allowed to fall below sixty (60) degrees Fahrenheit, while paint is being applied or while it is drying.

7. Priming Coats.

In general all exterior woodwork shall be given one priming coat of the same paint that is to be used for the finishing coats, thinned with pure spirits turpentine and pure raw linseed oil, as directed. This priming coat shall be applied as early as possible after such woodwork is erected, and well brushed into the pores of the wood.

Priming coats for window and door frames, structural steel and iron work, and the back of paneled wainscoting and partitions shall be applied in the shop before the wood or metal is subjected to dampness.

Priming of interior woodwork, plastered, concrete and brick surfaces will depend on the nature of the surfaces and the finishing coats to be used, as hereinafter specified.

8. Painting Exterior Wood Surfaces.

All exterior wood surfaces of every description, unless otherwise noted, shall receive, in addition to the priming coat, two (2) coats of lead and oil paint of approved brand and color. The third coat shall consist of the ready mixed paint as it comes from the container used without thinning.

Unless otherwise directed, exterior doors shall be painted three (3) coats on both sides, except where interior woodwork is to be varnished, in which case the outside only will be painted and the inside finished as described in paragraph 11. Tops and bottoms of doors shall be painted three (3) coats.

9. Finishing Interior Woodwork.

Interior wood surfaces shall be finished by one of the following methods or by a combination of these methods, as may be designated or as directed by the Engineer:

1. Painting with three coats of lead and oil paint.
2. Finishing in natural wood colors.
3. Staining and varnishing.
4. Enameling.

10. Painting Interior Wood Surfaces.

Where interior wood surfaces are to be painted, such surfaces shall receive, in addition to the priming coat, two (2) coats of an approved brand of lead and oil paint, using such colors as will conform to the Company's standard practice or as may be directed by the Engineer.

11. Staining and Varnishing Interior Wood Surfaces.

Where interior wood surfaces are to be finished with varnish, the work shall be done as follows:

(a) Natural Finish:

1. (For Open Grain Woods, Such as Mahogany, Ash, Chestnut, etc.):

The surface shall be sandpapered smooth and all nail holes stopped with putty, using putty colored to match the wood. Then apply one coat of paste filler and before the filler has hardened, rub off clean, rubbing across the grain. Allow the filler to harden 24 hours and sandpaper with fine sandpaper. Next apply one coat of orange or white shellac, depending on whether a dark or light finish is desired, and two coats of first quality interior varnish. At least 48 hours shall be allowed for drying between coats. The final finish shall be dull or polished, as directed by the Engineer. For a dull finish, rub with powdered pumice and water 72 hours after the final coat is applied.

2. For finishing close grained woods, such as pine, cypress, birch, maple, etc., use the method described for open grained woods with the omission of the paste filler.

(b) Stain and Varnish Finish:

1. (For Open Grain Woods).—After sandpapering the surface and puttying nail holes, apply one coat of oil stain wiped off, one coat of filler rubbed off, one coat of orange or white shellac, and two coats of first quality interior varnish. After filler has hardened 24 hours, sandpaper as described in paragraph (a) of this section, and finish final coat of varnish with either dull or gloss finish, as directed.

2. (For Close Grain Woods).—Apply one coat of approved oil stain, one coat of shellac and two coats of interior varnish, allowing each coat to dry before another is applied. Finish final coat of varnish with dull or gloss finish as directed.

12. Exterior Varnishing.

Where exterior woodwork is to be finished with varnish, or with stains and varnish, first apply one light coat of a mixture of 25 per cent. pure linseed oil and 75 per cent. pure spirits of turpentine, allow to dry and sandpaper, and then follow the specifications as given in paragraph 11, except that exterior spar varnish shall be used and the coat of shellac omitted.

13. Enameled Finishes on Wood or Plastered Surfaces.

Where enameled finishes are called for on wood or plastered surfaces, these surfaces shall be given five (5) coats of an approved enamel, thinned and applied in accordance with the manufacturer's instructions.

14. Finishing Wood Floors.

Wood floors shall be finished by one of the following methods as directed by the Engineer:

(a) Oiling with linseed oil (for woods such as maple or yellow pine).

Floors to be oiled shall be given three (3) coats of linseed oil, heated as nearly as possible to the boiling point. Ample time for absorption shall be allowed between each coat, and the floor shall not be used until the third coat has thoroughly dried.

(b) Finishing with varnish (for woods such as yellow pine, oak, etc.).

Floors to be finished with varnish shall be given one coat of floor varnish, thinned by adding one pint of turpentine to each gallon of varnish, and two coats of first quality elastic floor varnish. The floor shall be lightly sandpapered with fine sandpaper after the first varnish coat is dry. Oak floors shall be given one coat of paste filler, rubbed off, before the first varnish coat is applied.

15. Painting Structural Steel and Iron Work.

All structural steel and iron work, including pipe railings and castings, in addition to the shop priming coat specified in the section of these specifications covering "Steel and Iron Work" shall be given two (2) coats of the Company's standard exterior or interior paint as directed. Surfaces in contact or inaccessible after erection shall be given one (1) field coat before assembly or erection.

16. Painting Sheet Metal Work.

All sheet metal work (other than copper), including flashings, gutters, rain conductors, skylight frames, and metal roofs, shall be given three (3) coats of an approved metal paint, of such colors as may be directed by the Engineer. Surfaces of tin or galvanized sheet metal work and iron and steel in connection therewith, shall be thoroughly cleaned of grease, oil and traces of soldering flux before any paint is applied. Surfaces that will be unexposed after being placed and the under side of metal roofing shall be given one coat of paint before being installed. Before the priming coat is applied to galvanized sheet metal work, the surfaces shall be washed with a weak solution of vinegar, or a solution of sal-soda and water, using one pound of soda to three gallons of clean water. This wash shall be allowed to dry twenty-four (24) hours before the priming coat of paint is applied. Surfaces inaccessible after erection shall be given a priming coat and one other coat before being erected Paint shall be applied with hand brushes and well rubbed in. No dipping will be permitted.

17. Painting Plastered Surfaces.

After they are thoroughly dry, plastered walls and ceilings shall be given one coat of approved alkali-proof wall size and two (2) coats of approved interior wall paint with flat or eggshell finish, applied strictly in accordance with the manufacturer's directions. Each coat shall be allowed to dry not less than twenty-four (24) hours before the next coat is applied.

18. Painting Brick and Concrete Walls.

Interior brick and concrete wall surfaces except in basements and roundhouses shall be given three (3) coats of lead and oil flat wall paint of colors selected by the Engineer. Care shall be taken to see that these surfaces are free of all moisture before any paint is applied.

19. Painting Piping and Radiators.

Exposed piping and radiators in waiting rooms, offices, living rooms, lavatories, etc., shall be given one priming coat and two finishing coats of paint of an approved brand and color. Surfaces subjected to heat, such as steam piping and radiators, shall be painted with heat-resisting paints.

Exposed piping in basements, shop buildings, etc., and concealed piping which is not to be covered shall be painted two (2) coats.

Covered piping shall be given one coat of paint before the covering is applied, and the covering when in place shall be given two (2) coats of paint of approved brand and color.

20. Painting Interior of Roundhouses.

The interior walls, posts, etc., of frame roundhouses and all wood framing and sheathing of all roundhouses shall be given two coats of light colored fire-resisting paint. For a distance of six (6) feet above the floor all walls, posts, etc., shall be given two (2) coats of lead and oil paint of a dark color as selected by the Engineer.

All interior brick and concrete walls in roundhouses shall be given one (1) coat of light colored cold water paint or whitewash from a point six (6) feet above the floor to the under side of the roof, and three (3) coats of dark colored lead and oil paint from the floor to a height of six (6) feet. Cold water paint must be carefully brushed in so that one application will entirely cover the masonry surfaces with an opaque coat.

21. Staining Shingles.

All shingles on roofs and walls shall be dipped or given two brush coats of approved creosote shingle stain. The stains shall be kept thoroughly stirred and shall be applied without dilution or adulteration to the thoroughly dry shingles. In dipping all shingles shall be immersed butt end first to a depth of three-fourths the length of the shingle.

22. Sign Painting and Lettering.

The Contractor shall paint all necessary names, letters and numbers on all doors, signs, notice boards, etc. Letters and numbers shall conform to the Company's standard as to size and style, and the work shall be done by skilled sign painters.

23. Samples of Painting.

Before beginning any painting the Contractor shall submit for the approval of the Engineer two (2) samples of every kind of finish on wood blocks, and the final finishes shall conform to the approved samples.

24. Glazing.

The Contractor shall furnish and set all glass of every description for window, door, transom, and ceiling sash, including metal sash and all glass in skylights and marquises. Sash must be primed and thoroughly dry before any glass is set.

All putty, excepting for metal sash, shall be first quality white lead putty mixed with pure linseed oil.

Unless otherwise marked on the drawings glass for wood sash shall be American, double strength, Class "A."

Glass for main entrance doors shall be polished ¼ inch plate glass.

Glass for skylights, marques, metal sash and metal doors, unless otherwise specified or called for on the drawings, shall be one-quarter inch (¼") factory ribbed wire glass.

Where opaque or figured glass is called for on the drawings, this shall be Florentine, Maze, or other "approved" figured glass.

Samples of all glass to be used shall be submitted to the Engineer for approval, and all glass to be used in the work must conform strictly in quality with the approved samples.

Glazing in Metal Sash.—Glass in metal sash and doors shall be bedded in litharge putty, then clips or stops applied, back puttied and neatly face puttied; finished surface of putty shall show absolutely smooth, true and free from sags or wrinkles.

Glazing in Wood Sash.—Glass in wood sash shall be back puttied, securely fastened with glaziers' points and neatly face puttied.

Glazing in Doors.—Glass in wood doors shall be fastened in place with removable wood stops.

Glazing Skylights and Marquises.—Glass in skylights and marquises shall be secured in place by the use of copper strips and copper screws and shall be made watertight.

25. Final Cleaning.

Before the building is tendered for final acceptance all broken glass shall be replaced, all glass of every description shall be thoroughly cleaned, and all paint stains removed from floors, walls, brickwork, marble and finished surfaces.

26. Application of General Conditions.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

SECTION 10

Plumbing

1. General.

The Contractor shall furnish all labor, material, tools and equipment, except as otherwise noted, to entirely complete the plumbing work, as specified or shown on drawings, including all fixtures, drains, water supply and all piping and sewers to a point five feet outside of building, all of which shall be considered as included in the plumbing work. Piping and sewers beyond a point five feet outside of building will be paid for on a unit price basis.

2. Excavation.

The Contractor shall do all necessary excavation of every description in connection with the plumbing work. The bottom of all trenches shall be carefully shaped to give uniform bearing for pipes. No backfilling shall be done until test and inspection have been made by the Engineer. Trenches shall be filled by ramming and puddling, the filling being brought to the proper grade.

3. Arrangement of System.

The arrangement of the system shall be as direct as possible, avoiding unnecessary bends and offsets. Vertical runs of cast iron pipe shall be firmly secured in position with strong iron pipe hooks placed under each hub, and stacks must be properly supported at the bottom. Horizontal runs under floors must be placed in position and tested before floors are laid.

Changes in direction of soil and sewer pipe shall be made by means of one-eighth (1/8) bends and "Y" branches and not with one-quarter (1/4) bends.

Fittings receiving risers shall be set with the top of fitting at the surface of the finished floor and shall be securely clamped in position.

All horizontal runs of sewers 6 inches or less shall have a minimum fall of 1/8 inch per foot.

4. Cast Iron Pipe and Fittings.

Concealed soil, waste, drain, sewer and vent pipes in building shall be extra heavy cast iron soil pipe. Pipe shall have the maker's name cast thereon and shall be in lengths not less than five (5) feet. It shall be sound and free from defects and with the inner and outer surfaces concentric and smooth and of the following weights per linear foot.

2 inches	5½ lb.	6 inches	20 lb.
3 inches	9½ lb.	7 inches	27 lb.
4 inches	13 lb.	8 inches	33½ lb.
5 inches	17 lb.	10 inches	45 lb.

Fittings for cast iron pipe shall be extra heavy cast iron of the same make as the soil pipe, and shall be of the same inside diameter as pipe with which they are connected. Unless otherwise specified, cast iron pipe and fittings must be coated with hot asphaltum both inside and outside by dipping. Fittings for the junction of cast and wrought iron pipe shall be cut at one end with full threads, and fittings, supporting risers shall have proper shoes cast on them.

Water supply pipes larger than 2½ inches diameter located below ground shall be Class "B" cast iron pipe, in accordance with the specifications of the American Water Works Association, unless local conditions require the use of heavier pipe.

5. Wrought Iron Pipe.

Wrought iron pipe shall be galvanized, genuine wrought iron of Standard weights and dimensions cut with full threads with all burrs carefully reamed out before connecting. Fittings used with wrought iron soil and waste pipe shall be recessed cast iron drainage fittings. Fittings used with galvanized water supply pipe, shall be heavy beaded galvanized malleable iron except where brass is specified.

All exposed soil, waste and vent pipes in the building shall be genuine wrought iron.

6. Lead Pipe.

Lead pipe shall be of the weight known as "Strong" lead pipe. All water supply pipes 2½ inches or smaller, located below ground, shall be lead pipe.

7. Brass Pipe.

All exposed supply or waste pipe to fixtures, including connections to faucets, etc., shall be nickel plated brass, unless otherwise specified.

Brass pipe for water supply shall be seamless drawn semi-annealed brass pipe of iron pipe sizes, heavily nickel plated. Brass pipe fittings shall be heavy beaded cast brass heavily nickel plated.

8. Fixtures.

The Contractor shall furnish and install complete, in proper working order, the following fixtures, locations of which are shown on the drawings. Fixtures shall be as manufactured by .... or approved equal, and shall conform to the typical types of fixtures, shown in Appendix "A" of this specification.

List of Fixtures

....

....

....

9. **Joints and Connections.**

Joints for cast iron pipe shall be made with picked oakum and moulten lead, and shall be air and water tight. Twelve ounces of lead shall be used for each inch of diameter of pipe for each joint. Each joint must be filled at one pouring.

Connections between iron and lead pipes shall be made with brass ferrules and neatly wiped joints. Connections between outlet of fixtures and vertical soil pipes may be made by means of sanitary tees, but all connections between horizontal runs must be made by means of "Y" branches. Openings for connections shall be closed with plugs until tested. Hand holes shall be closed immediately upon completion of each portion of the work and all sewers kept clean.

10. **Suspended Sewers and Risers.**

All suspended sewers, wastes and downspouts, also risers in buildings, shall be genuine wrought iron pipe, and points of support shall not be more than five (5) feet apart for horizontal runs.

11. **Drains.**

The Contractor shall install the piping for all drains of every description, including all branches, traps and accessories necessary to make the plumbing system complete.

12. **Valves.**

In cases where there is danger of backwater from the sewer, all sewer and drain lines shall be equipped in the building with a backwater valve, properly set in a pit for accessibility. Shutoff valves throughout the plumbing system except in connection with fixtures shall be extra heavy gate valves, equipped with iron hand wheels. Valves 2 in. and under shall be brass of best quality, larger valves shall have iron bodies and brass trimmings. All valves shall be located in convenient and accessible places.

13. **Sizes of Pipes.**

The following shall be the minimum sizes of pipe for water supply in the cases listed:

Main supply to building	(. , .)
To toilet rooms	¾ in.
To individual sill cock	¾ in.
To individual sink	¾ in.
To individual urinal	½ in.
To individual lavatory	½ in.
To individual closet	½ in.
To heating boiler	¾ in.

Air chambers shall be provided in the water supply pipe at its connection to each fixture, to prevent water hammer. This chamber shall be equal, in capacity, to one foot of the supply pipe.

The minimum size of waste pipes for fixtures shall be as follows:

From individual closets	4 in.
From individual lavatories	$1\frac{1}{2}$ in.
From individual urinals	2 in.
From individual slop sinks	3 in.

The minimum sized vent pipes shall be as follows:

For closet traps	2 in.
For lavatory	$1\frac{1}{2}$ in.
For urinals	2 in.
For slop sinks	2 in.

14. Openings in Floors or Walls.

Wherever exposed plumbing pipes pass through floors or walls they shall be provided with galvanized iron pipe sleeves with nickel plated brass floor or ceiling plates. Wherever pipes pass through concrete or masonry, the contractor shall provide iron pipe sleeves of the requisite size, locating these for the masonry contractor, and assume all responsibility for their correct location.

15. Soil and Vent Stacks.

Main stacks shall be extended through roof of building and to a height not less than twelve inches (12″) above the top thereof. Stacks extending through the roof must increase their diameter two (2) inches at a point six (6) inches below the roof. No stack extending through the roof shall be less than four (4) inches in diameter.

Fixtures shall be revented except in cases where but a single fixture is attached to a stack, in which case this fixture need not be revented. Vent fittings shall be combination fittings of a type that will comply with local ordinances. Branch vents shall be cast iron and must be connected into the main vent stack below the roof. That portion of the stack above the roof shall be properly flashed with four (4) pound sheet lead with fifteen-inch (15″) square collar. Flashing shall be turned down into the top of stack, and shall be made watertight.

16. Meter, Pressure Regulator, Etc.

The Contractor shall install in a suitable concrete pit a water meter of an approved type, and make the necessary connection to the water main. Where the pressure in the main exceeds forty (40) pounds he shall install in connection with the meter a water pressure regulator of an approved type, properly adjusted to protect the fixtures in the building. Provide and set on the main supply line a stop and waste cock which will drain the entire piping system in the building. Provide in the pit with the meter a valve which will cut off the entire water supply from the building.

17. Traps and Cleanouts.

Approved traps with cleanouts, equipped with brass plugs, shall be placed under each fixture. Brass plugs for cleanouts shall be placed at the foot of each soil and waste riser above the floor and at all changes in direction of soil and waste pipes. Cleanouts connected below floors must be brought up level with floors by means of "Y" fittings and one-eighth (1/8) bends. All plugs must be full size of pipes.

18. Pipe Covering.

All hot water piping shall be covered with 3/4-in. wool felt covering of an approved brand, lined with asbestos on the inside and covered with eight-ounce canvas jacket, banded with three (3) lacquered bands to each section.

Cold water pipe, in concealed positions, behind plastered walls or ceilings or carried in tunnels with steam or hot water heating pipes, shall be covered as described above, except that the lining shall be of tarred felt instead of asbestos. Fittings shall be covered with hair felt, with canvas jackets. All covering shall be applied in a manner to prevent sweating.

19. Slate Compartment Work.

The Contractor shall furnish and set all slate compartment work called for on drawings, complete, in accordance with details. Slate shall be black ribbed slate, of best quality. Trimmings, including coat hooks and toilet paper holders, shall be nickel-plated brass.

Doors for slate water closet stalls will be furnished and installed by carpenters, but hardware for same shall be furnished by the plumbing contractor. Doors for wooden closet stalls will be furnished and installed by carpenter, complete with hardware.

20. Tests.

The system shall be subject to the following test, to be made entirely at the expense of the Contractor:

After all pipes are "roughed in" and before the final connections are made with fixtures and sewer, all openings shall be closed and pipes filled with water to roof line. The water shall be maintained at this level until the job has been inspected and approved.

Should any defect appear, it shall be remedied and any defective material shall be replaced with sound material. After the water has been turned on and the traps filled, a peppermint test shall be made by placing two ounces of oil of peppermint in each stack. The system, with all traps full, must retain the peppermint odor from all parts of the building.

These tests shall be repeated until the work is approved by the Engineer.

21. Gas Piping.

The Contractor shall install piping for gas with outlets located where shown on drawings. The supply line shall be of a size recommended by Gas Company supplying the service and all piping shall meet the approval of the Gas Company. Pipes shall be coated with asphaltum after installation. A meter shall be installed as required by the rules of the Gas Company, with necessary valves and shutoff. Gas piping shall be tested as required by the Gas Company and certificate of inspection delivered to the Railway Company. The gas meter shall be placed in a convenient and accessible location.

22. Fire Protection.

The Contractor shall install, complete, all supply lines required for fire protection, including all connections to water main, and all fire hydrants and connections as indicated on the drawings or specified.

All pipe for outside fire protection lines shall conform to and be laid in accordance with the American Water Works Association Specifications for cast iron water pipe and special castings.

Where the size of fire lines is 6 in. or larger, 6-in. two-way standard hydrants equipped with drain and auxiliary valves shall be used. Where fire-fighting apparatus is to be provided inside the building, independent standpipes, 2½ in. or larger, shall be installed so as not to be more than 200 ft. apart on each floor. Each standpipe shall be equipped with a standard 2½-in. threaded hose connection located five (5) feet above the floor level. Each standpipe shall be provided with a 2½x1½-in. reducing coupler, an approved hose reel, or rack, together with hose, nozzle and couplings, as specified. Not more than 100 ft. of hose shall be provided for each connection, but the lengths must be such that every part of each floor may be reached.

Where buildings are heated Underwriters' 1½-in. linen hose must be used. Where buildings are not heated Underwriters' 1½-in. cotton rubber-lined hose must be used. Hose for outside use shall be Underwriters' approved 2½-in. double jacket fire hose.

Nozzles for outside hose shall be Underwriters' play pipe with 1⅛-in. orifice. Each hose inside of buildings shall be equipped with a brass nozzle 12 in. long, with a ½-in. orifice.

All fire-fighting apparatus shall be in conformity with the requirements of the National Board of Fire Underwriters. It shall also conform to the requirements of the Local Fire Department so far as hose connections are concerned.

23. Local Rules and Ordinances.

The Contractor shall comply in all cases with the local sanitary, gas and fire protection ordinances, and shall obtain and pay for all permits and inspection fees.

24. General Conditions.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed and accepted.

The general conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specifications.

The Committee offers as information the following types of plumbing fixtures for guidance in use of these plumbing specifications to be used as Appendix "A," referred to in paragraph 8, Fixtures.

A.R.E.A.

TYPICAL PLUMBING FIXTURES

FOR

RAILWAY BUILDINGS

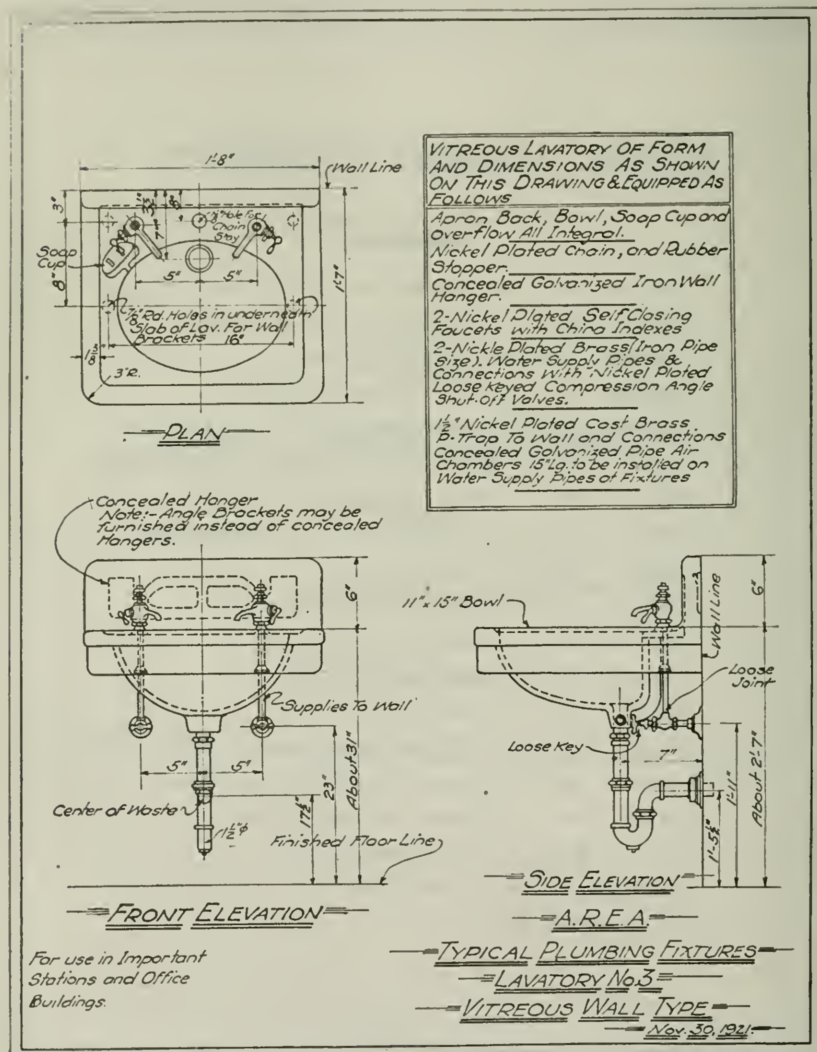
APPENDIX A

SUPPLEMENTING PLUMBING SPECIFICATIONS

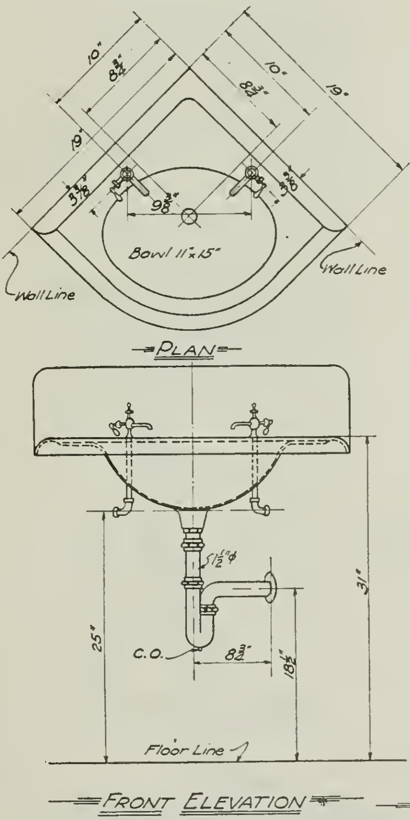
TYPICAL PLUMBING FIXTURES

INDEX

Lavatory No. 1 - Enameled Cast Iron Wall Type
Lavatory No. 2 - Enameled Cast Iron Corner Type
Lavatory No. 3 - Vitreous Wall Type
Lavatory No. 4 - Vitreous Corner Wall Type
Lavatory No. 5 - Double Battery Type
Closet No. 1 - Syphon Jet Seat Operating Flush Valve Type
Closet No. 2 - Syphon Jet Seat Operating Type
Closet No. 3 - Wash Down Jet Seat Operating Type
Closets No. 4 & 5 - Frost Proof Types
Closet Stall No. 1 - Slate Type Without Doors
Closet Stall No. 2 - Slate Type With Doors
Closet Stall No. 3 - Wood Type With Doors.
Urinal No. 1 - Floor Type
Urinal No. 2 - Automatic Trough Type
Urinal No. 3 - Automatic One Piece Trough Type
Urinal No. 4 - Syphon Jet Vitreous Type
Drinking Fountain No. 1 - Pedestal Type
Drinking Fountain No. 2 - Wall Type
Slop Sink With Back.



VITREOUS LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS
Apron Back, Bowl, Soap Cup and overflow All Integral.
Nickel Plated Chain, and Rubber Stopper.
Concealed Galvanized Iron Wall Hanger.
2-Nickel Plated Self Closing Faucets with China Indexes
2-Nickle Plated Brass (Iron Pipe Size). Water Supply Pipes & Connections With Nickel Plated Loose keyed Compression Angle Shut-Off Valves.
1½" Nickel Plated Cast Brass P-Trap To Wall and Connections Concealed Galvanized Pipe Air Chambers 15" Lg. to be installed on Water Supply Pipes of Fixtures
Wall Line
Soap Cup
Chain Stay
⅞" Rd. Holes in underneath Slab of Lav. For Wall Brackets
PLAN
Concealed Hanger
Note:- Angle Brackets may be furnished instead of concealed Hangers.
Supplies To Wall
Center of Waste
Finished Floor Line
About 31"
FRONT ELEVATION
11" x 15" Bowl
Loose Joint
Loose Key
About 2'-7"
SIDE ELEVATION
For use in Important Stations and Office Buildings.
A.R.E.A.
TYPICAL PLUMBING FIXTURES
LAVATORY No 3
VITREOUS WALL TYPE
Nov. 30, 1921.



ENAMELED IRON ROLL RIM CORNER LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS

Cast Iron Lavatory enameled inside and painted outside, having Slab Back Bowl and overflow integral

Concealed Galvanized Iron Wall Hangers

2 - Nickel Plated Fuller Faucets

2 - Crawford Connections

1 - 1½" Nickel Plated "P" Trap No Vent

1 - 1½" Sweat Bushing

For use in Section Houses
Less Important Stations,
Freight Rooms, and Offices
and Shops

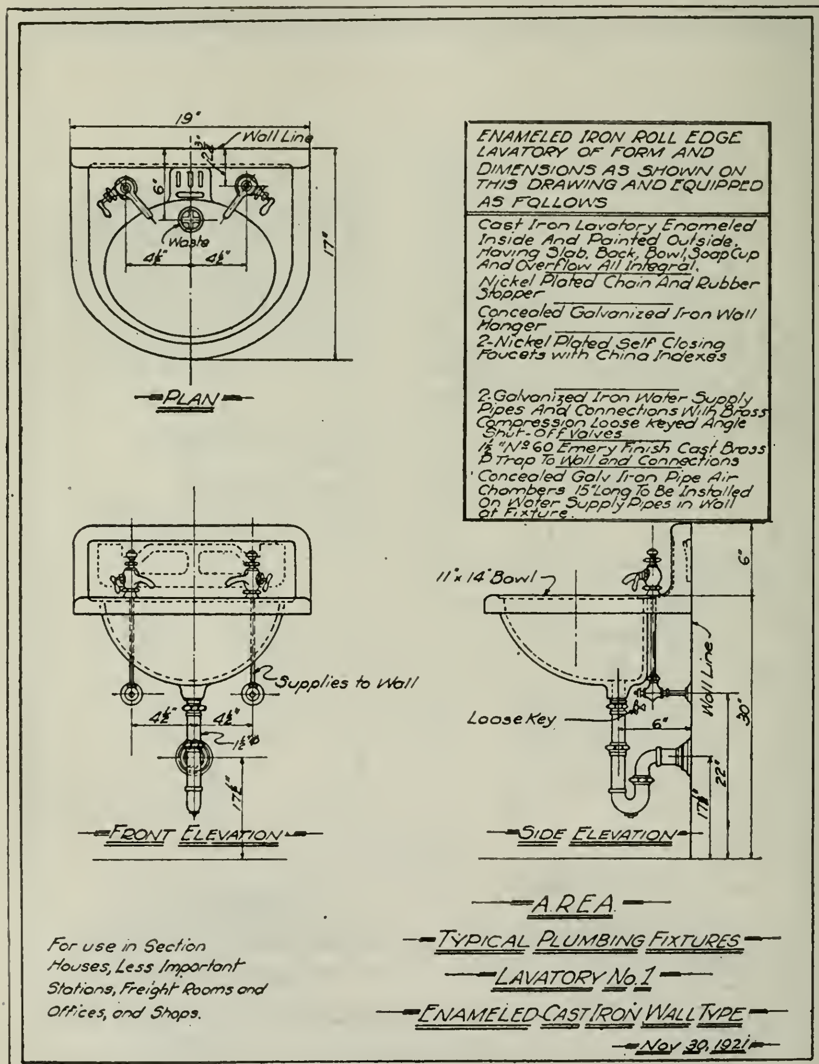
A.R.E.A.

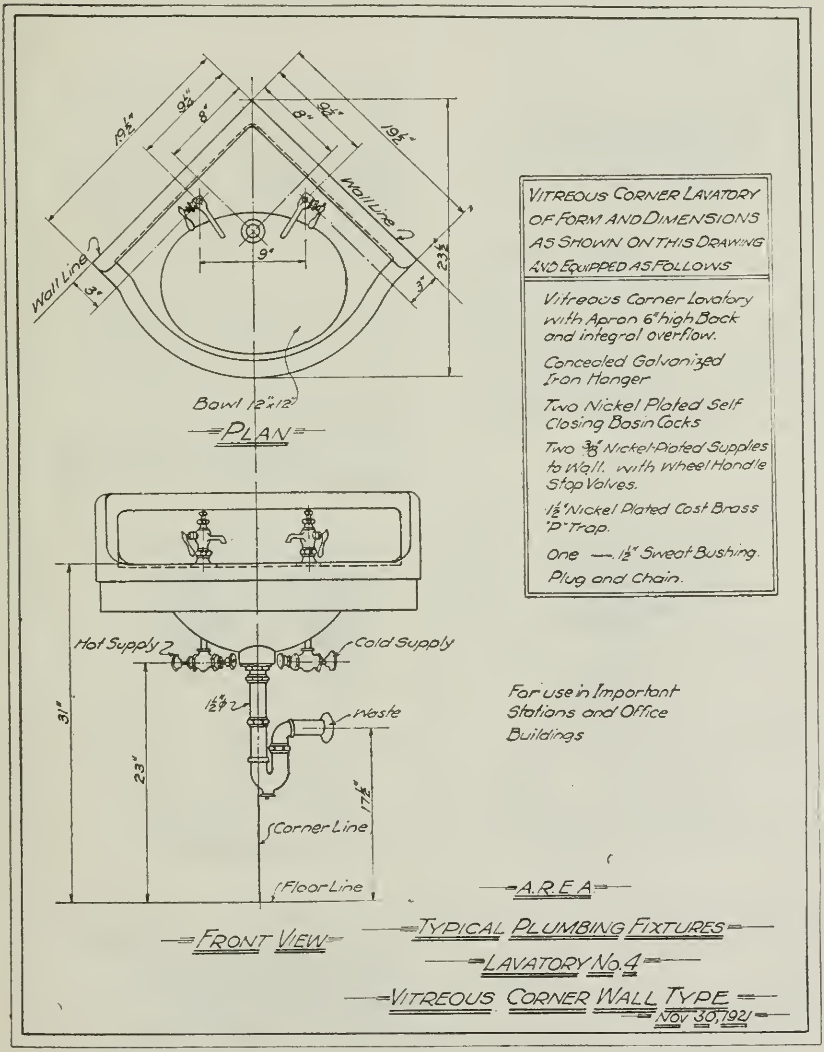
TYPICAL PLUMBING FIXTURES

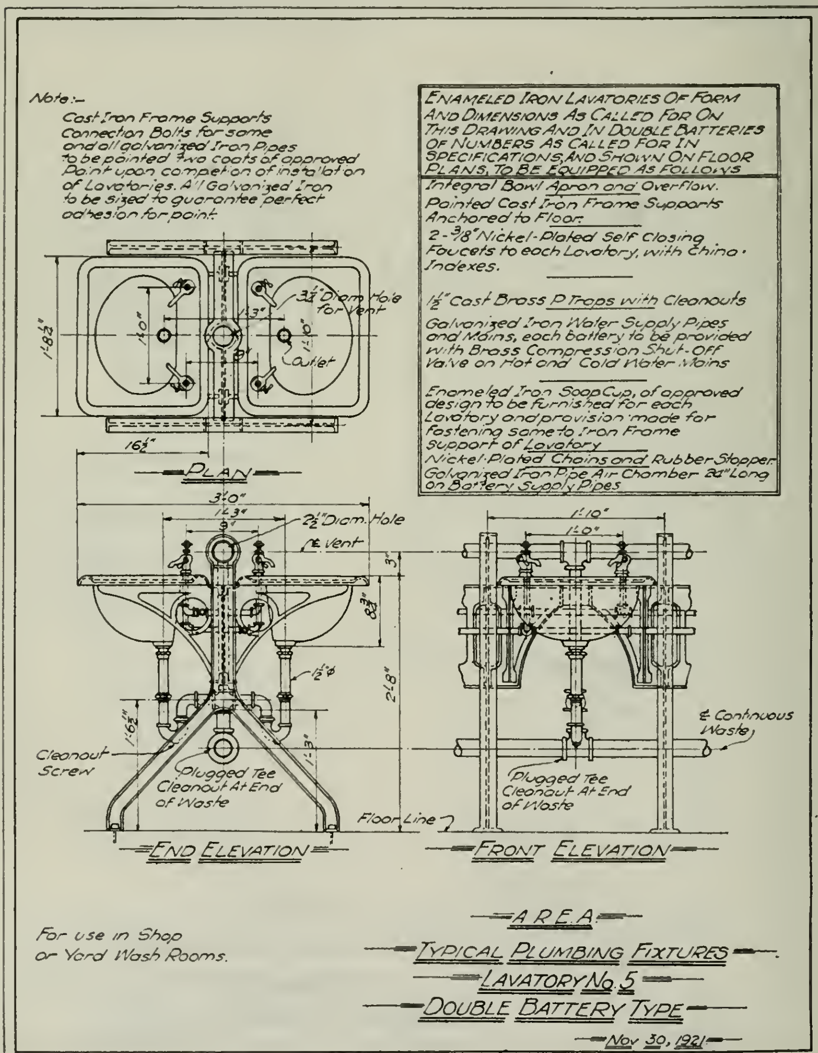
LAVATORY No. 2

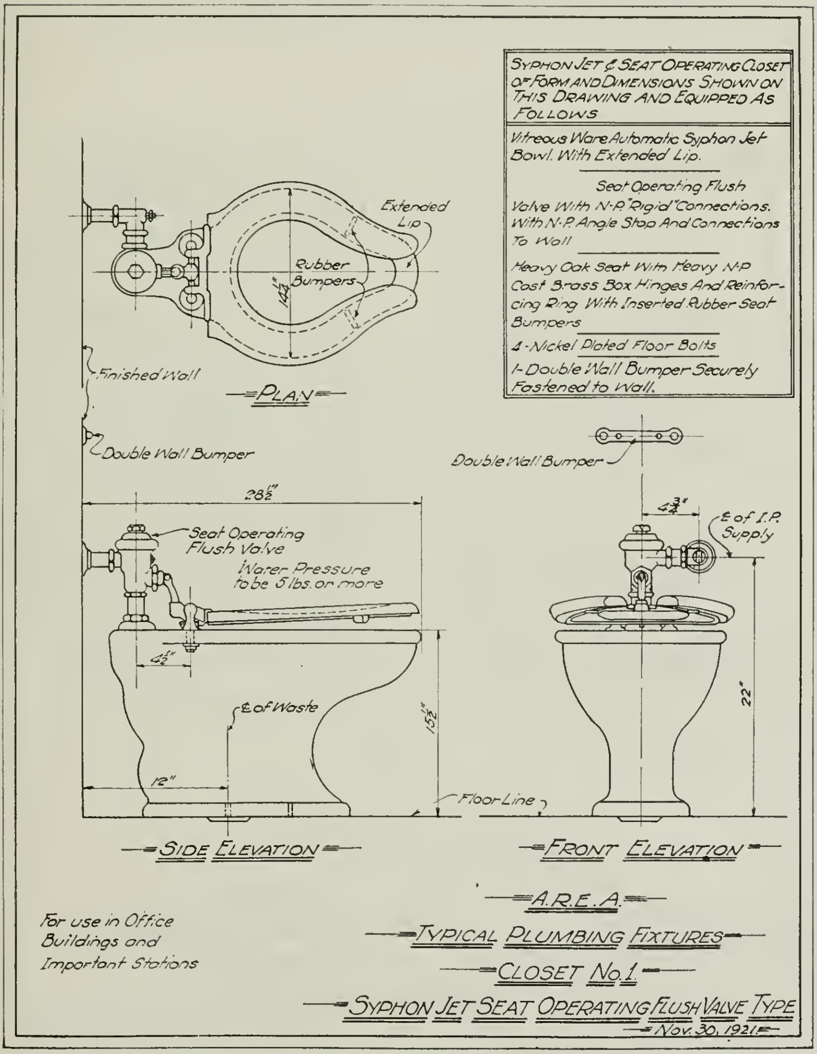
ENAMELED CAST IRON CORNER TYPE

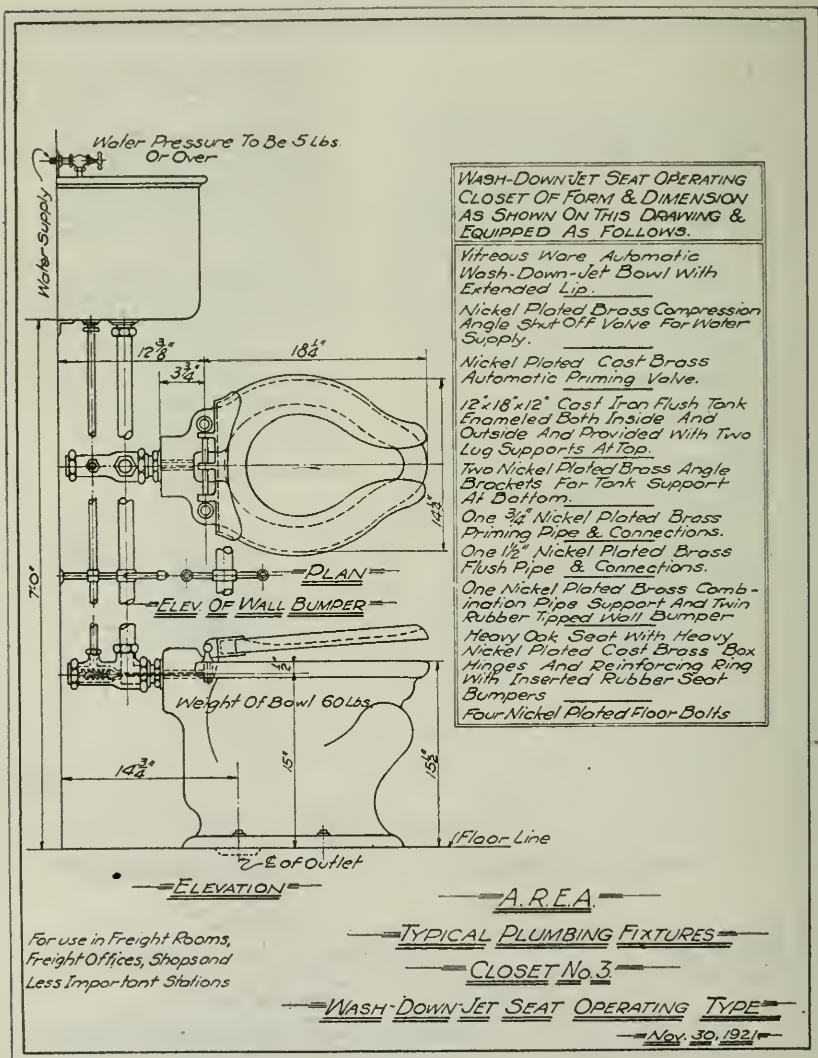
Nov. 30, 21

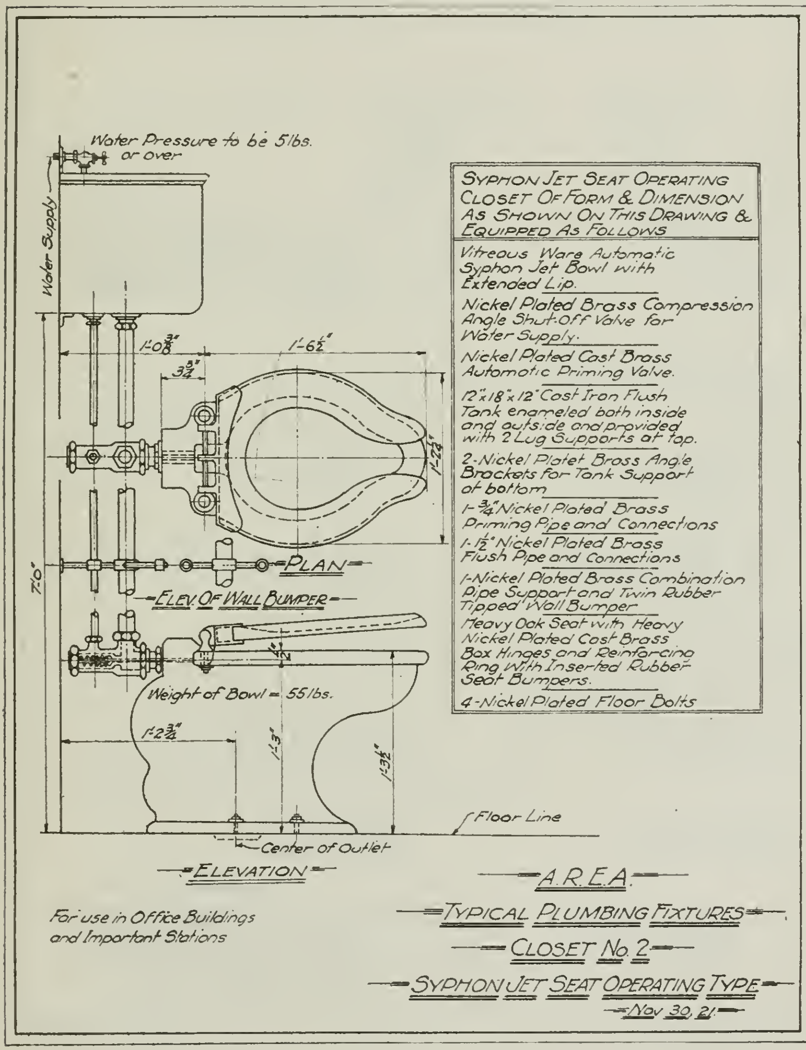

ENAMELED IRON ROLL EDGE LAVATORY OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS
Cast Iron Lavatory Enameled Inside And Painted Outside, Having Slab, Back, Bowl, Soap Cup And Overflow All Integral.
Nickel Plated Chain And Rubber Stopper
Concealed Galvanized Iron Wall Hanger
2-Nickel Plated Self Closing Faucets with China Indexes
2-Galvanized Iron Water Supply Pipes And Connections With Brass Compression Loose Keyed Angle Shut-Off Valves
1¼" Nº 60 Emery Finish Cast Brass P Trap To Wall and Connections
Concealed Galv Iron Pipe Air Chambers 15" Long To Be Installed On Water Supply Pipes in Wall at Fixture.
19"
Wall Line
6"
Waste
4½"
4½"
17"
PLAN
Supplies to Wall
1¼"
17½"
FRONT ELEVATION
11" x 14" Bowl
6"
Wall Line
Loose Key
30"
22"
17½"
SIDE ELEVATION
For use in Section Houses, Less Important Stations, Freight Rooms and Offices, and Shops.
A.R.E.A.
TYPICAL PLUMBING FIXTURES
LAVATORY No. 1
ENAMELED CAST IRON WALL TYPE
Nov. 30, 1921

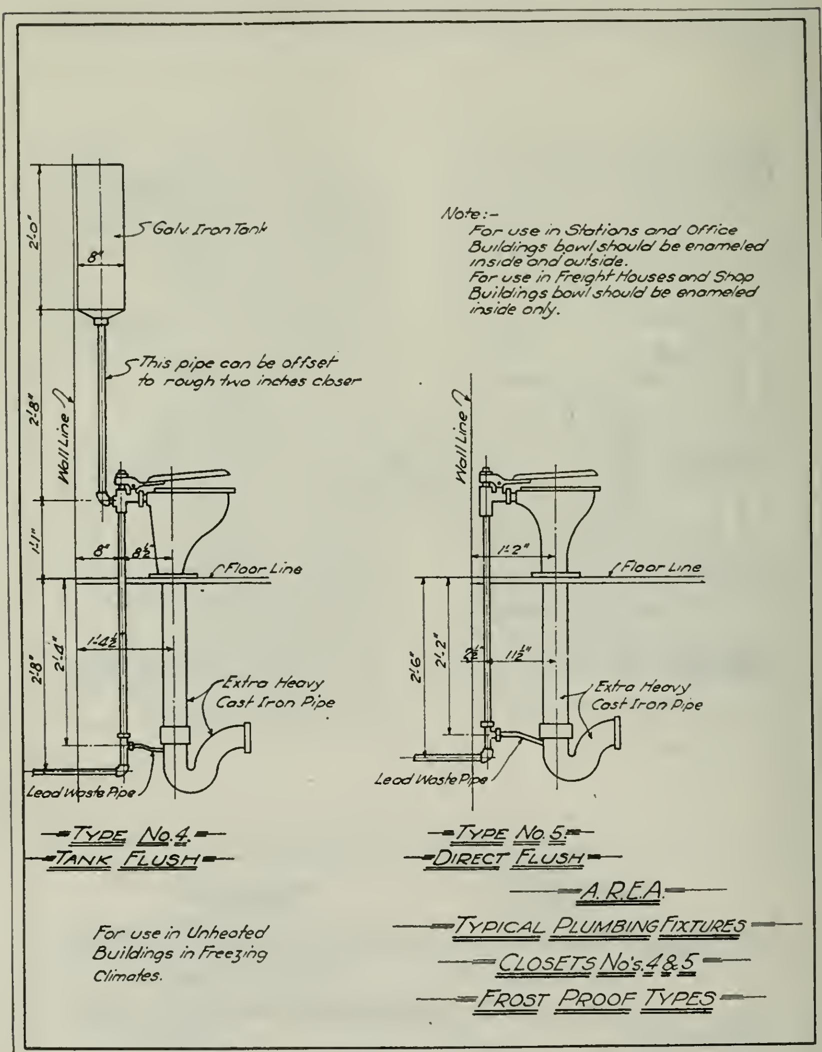

19½"
9¼"
8"
8"
9¼"
19½"
Wall Line
Wall Line
9"
3"
3"
23½"
Bowl 12"x12"
PLAN
VITREOUS CORNER LAVATORY
OF FORM AND DIMENSIONS
AS SHOWN ON THIS DRAWING
AND EQUIPPED AS FOLLOWS
Vitreous Corner Lavatory with Apron 6" high Back and integral overflow.
Concealed Galvanized Iron Hanger
Two Nickel Plated Self Closing Basin Cocks
Two ⅜" Nickel Plated Supplies to Wall. with Wheel Handle Stop Valves.
1½" Nickel Plated Cast Brass "P" Trap.
One — 1½" Sweat Bushing.
Plug and Chain.
Hot Supply
Cold Supply
1½"
Waste
31"
23"
17¼"
Corner Line
Floor Line
For use in Important Stations and Office Buildings
A.R.E.A.
FRONT VIEW
TYPICAL PLUMBING FIXTURES
LAVATORY No. 4
VITREOUS CORNER WALL TYPE
NOV 30, 1921

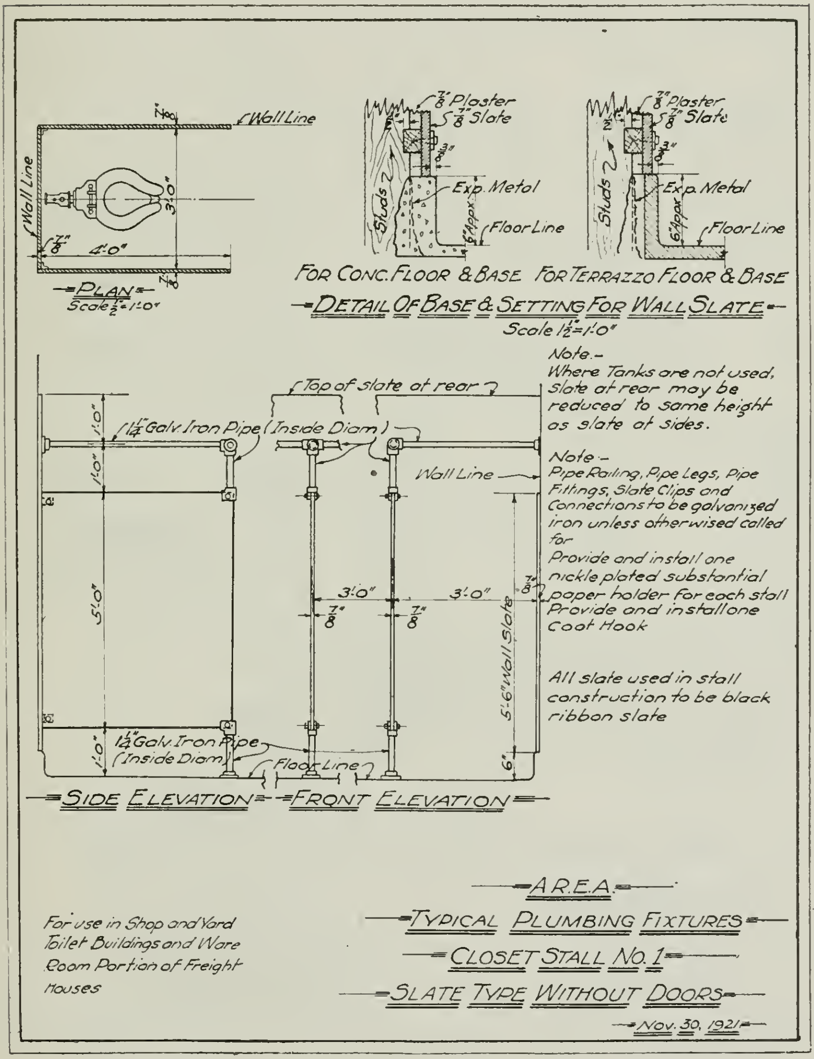

Note:-
Cast Iron Frame Supports
Connection Bolts for same
and all galvanized Iron Pipes
to be painted two coats of approved
Paint upon completion of installation
of Lavatories. All Galvanized Iron
to be sized to guarantee perfect
adhesion for paint.
ENAMELED IRON LAVATORIES OF FORM AND DIMENSIONS AS CALLED FOR ON THIS DRAWING AND IN DOUBLE BATTERIES OF NUMBERS AS CALLED FOR IN SPECIFICATIONS, AND SHOWN ON FLOOR PLANS, TO BE EQUIPPED AS FOLLOWS
Integral Bowl Apron and Overflow.
Painted Cast Iron Frame Supports Anchored to Floor.
2-3/8" Nickel-Plated Self Closing Faucets to each Lavatory, with China Indexes.
1½" Cast Brass P Traps with Cleanouts
Galvanized Iron Water Supply Pipes and Mains, each battery to be provided with Brass Compression Shut-Off Valve on Hot and Cold Water Mains
Enameled Iron Soap Cup, of approved design to be furnished for each Lavatory and provision made for fastening same to Iron Frame Support of Lavatory
Nickel-Plated Chains and Rubber Stopper.
Galvanized Iron Pipe Air Chamber 24" Long on Battery Supply Pipes
3½" Diam. Hole for Vent
Outlet
1'-8¾"
16½"
PLAN
3'-0"
1'-3"
9"
2½" Diam. Hole
℄ Vent
3"
8¾"
2'-8"
1½"φ
1'-6½"
1'-3"
Cleanout Screw
Plugged Tee Cleanout At End of Waste
Floor Line
END ELEVATION
1'-10"
1'-0"
℄ Continuous Waste
Plugged Tee Cleanout At End of Waste
FRONT ELEVATION
For use in Shop or Yard Wash Rooms.
AREA
TYPICAL PLUMBING FIXTURES
LAVATORY No. 5
DOUBLE BATTERY TYPE
Nov 30, 1921


SYPHON JET & SEAT OPERATING CLOSET OF FORM AND DIMENSIONS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS
Vitreous Ware Automatic Syphon Jet Bowl. With Extended Lip.
Seat Operating Flush Valve With N-P "Rigid" Connections. With N-P Angle Stop And Connections To Wall
Heavy Oak Seat With Heavy N-P Cast Brass Box Hinges And Reinforcing Ring With Inserted Rubber Seat Bumpers
4-Nickel Plated Floor Bolts
1-Double Wall Bumper Securely Fastened to Wall.
Extended Lip
Rubber Bumpers
$14\frac{3}{4}$"
Finished Wall
PLAN
Double Wall Bumper
Double Wall Bumper
$28\frac{1}{2}$"
Seat Operating Flush Valve
Water Pressure to be 5 lbs. or more
$4\frac{1}{2}$"
℄ of Waste
$15\frac{1}{2}$"
12"
Floor Line
$4\frac{3}{4}$"
℄ of I.P. Supply
22"
SIDE ELEVATION
FRONT ELEVATION
For use in Office Buildings and Important Stations
A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSET No. 1
SYPHON JET SEAT OPERATING FLUSH VALVE TYPE
Nov. 30, 1921

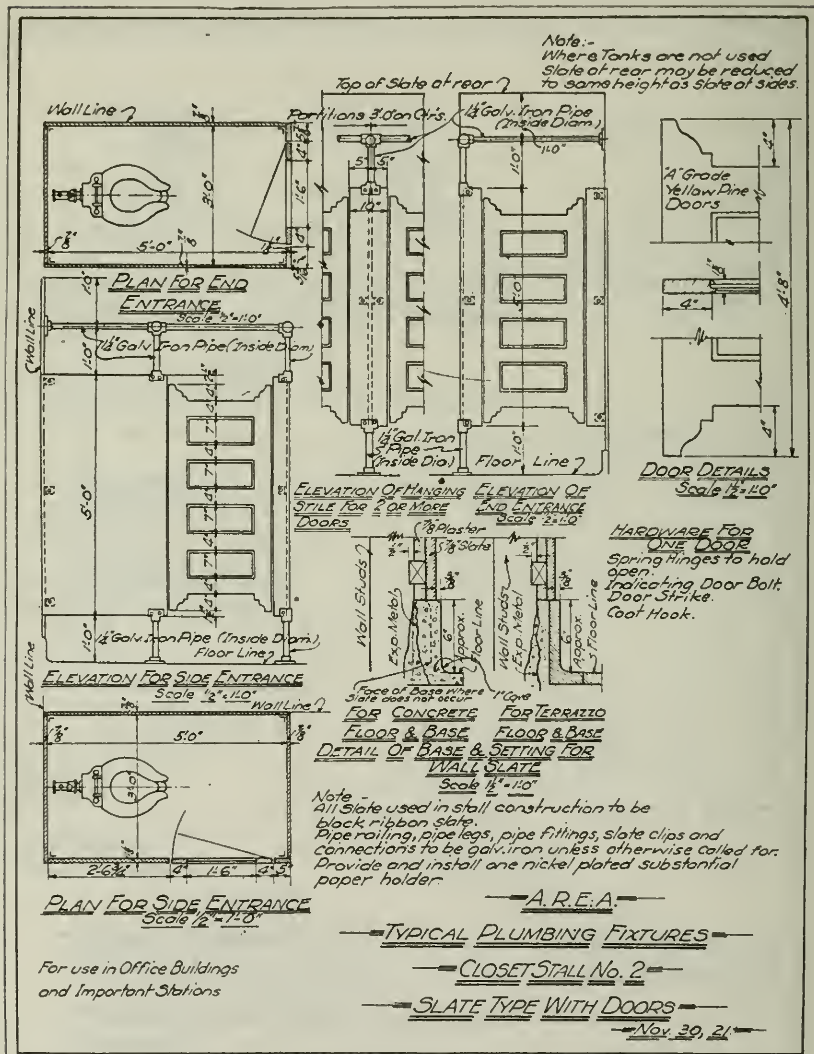

Water Pressure To Be 5 Lbs. Or Over
Water Supply
WASH-DOWN JET SEAT OPERATING CLOSET OF FORM & DIMENSION AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS.
Vitreous Ware Automatic Wash-Down-Jet Bowl With Extended Lip.
Nickel Plated Brass Compression Angle Shut Off Valve For Water Supply.
Nickel Plated Cast Brass Automatic Priming Valve.
12"x18"x12" Cast Iron Flush Tank Enameled Both Inside And Outside And Provided With Two Lug Supports At Top.
Two Nickel Plated Brass Angle Brackets For Tank Support At Bottom.
One 3/4" Nickel Plated Brass Priming Pipe & Connections.
One 1½" Nickel Plated Brass Flush Pipe & Connections.
One Nickel Plated Brass Combination Pipe Support And Twin Rubber Tipped Wall Bumper
Heavy Oak Seat With Heavy Nickel Plated Cast Brass Box Hinges And Reinforcing Ring With Inserted Rubber Seat Bumpers
Four Nickel Plated Floor Bolts
PLAN
ELEV. OF WALL BUMPER
Weight Of Bowl 60 Lbs.
7'0"
15"
Floor Line
℄ of Outlet
ELEVATION
For use in Freight Rooms, Freight Offices, Shops and Less Important Stations
A. R. E. A.
TYPICAL PLUMBING FIXTURES
CLOSET No. 3.
WASH-DOWN-JET SEAT OPERATING TYPE
Nov. 30, 1921

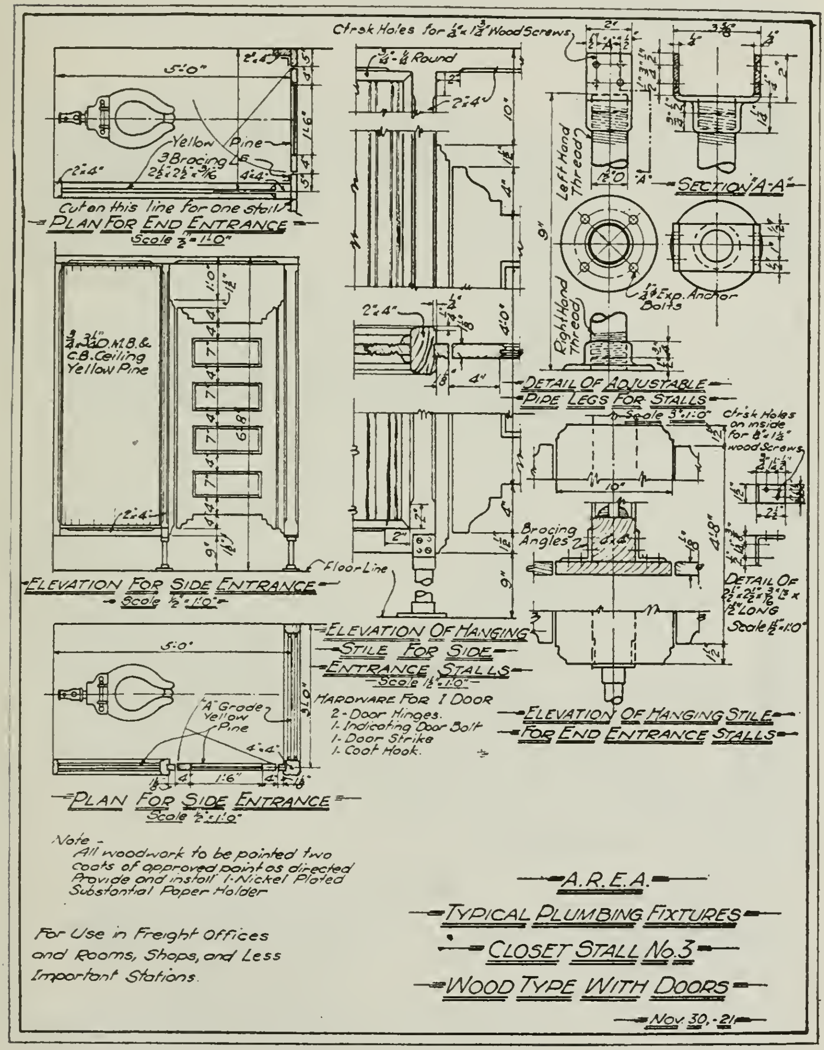

Water Pressure to be 5 lbs. or over
Water Supply
SYPHON JET SEAT OPERATING CLOSET OF FORM & DIMENSION AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS
Vitreous Ware Automatic Syphon Jet Bowl with Extended Lip.
Nickel Plated Brass Compression Angle Shut-Off Valve for Water Supply.
Nickel Plated Cast Brass Automatic Priming Valve.
12"x18"x12" Cast Iron Flush Tank enameled both inside and outside and provided with 2 Lug Supports at top.
2-Nickel Platet Brass Angle Brackets for Tank Support at bottom
1-3/4" Nickel Plated Brass Priming Pipe and Connections
1-1/2" Nickel Plated Brass Flush Pipe and Connections
1-Nickel Plated Brass Combination Pipe Support and Twin Rubber Tipped Wall Bumper
Heavy Oak Seat with Heavy Nickel Plated Cast Brass Box Hinges and Reinforcing Ring With Inserted Rubber Seat Bumpers.
4-Nickel Plated Floor Bolts
1'-0 3/8"
1'-6 1/2"
3 5/8"
1'-2 3/4"
PLAN
ELEV. OF WALL BUMPER
7'-0"
Weight of Bowl = 55 lbs.
1'-2 3/4"
1'-3"
1'-3 1/2"
Floor Line
Center of Outlet
ELEVATION
For use in Office Buildings and Important Stations
A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSET No. 2
SYPHON JET SEAT OPERATING TYPE
Nov 30, 21.

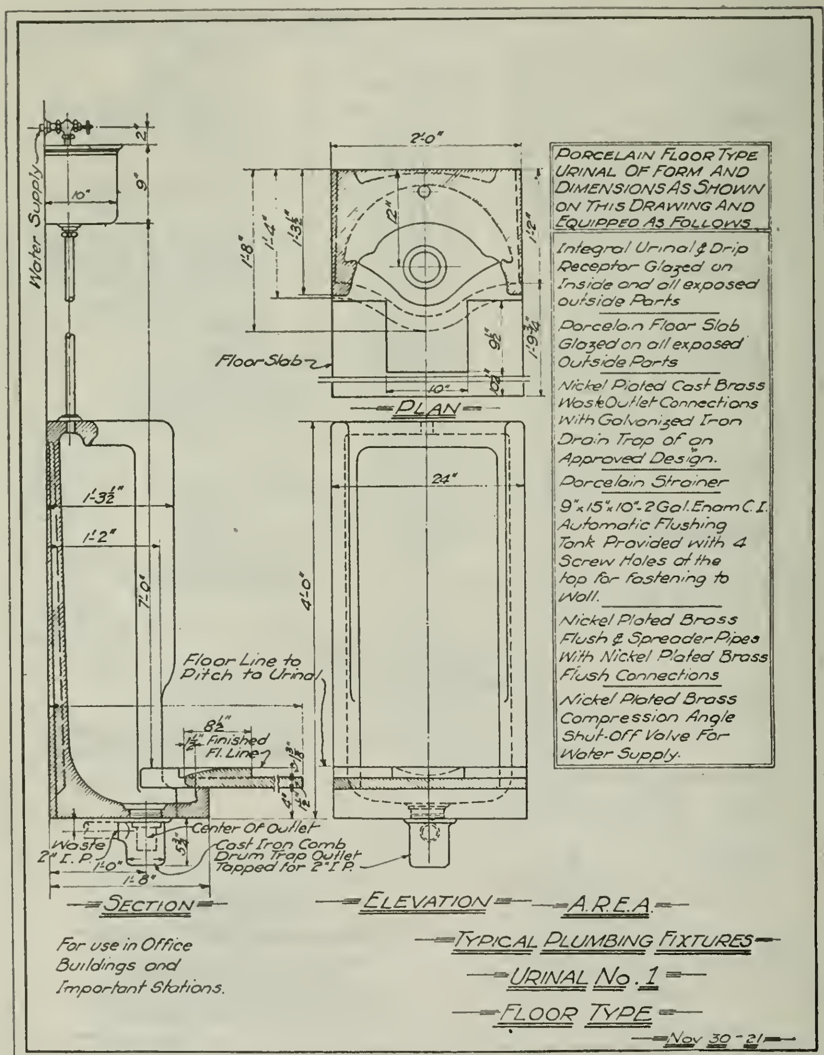

Note:-
For use in Stations and Office Buildings bowl should be enameled inside and outside.
For use in Freight Houses and Shop Buildings bowl should be enameled inside only.
Galv. Iron Tank
This pipe can be offset to rough two inches closer
Wall Line
Floor Line
Extra Heavy Cast Iron Pipe
Lead Waste Pipe
2'-0"
8"
2'-8"
1'-1"
8½"
1'-4½"
2'-4"
1'-2"
2'-6"
2'-2"
11½"
TYPE No. 4.
TANK FLUSH
TYPE No. 5.
DIRECT FLUSH
For use in Unheated Buildings in Freezing Climates.
A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSETS No's. 4 & 5
FROST PROOF TYPES

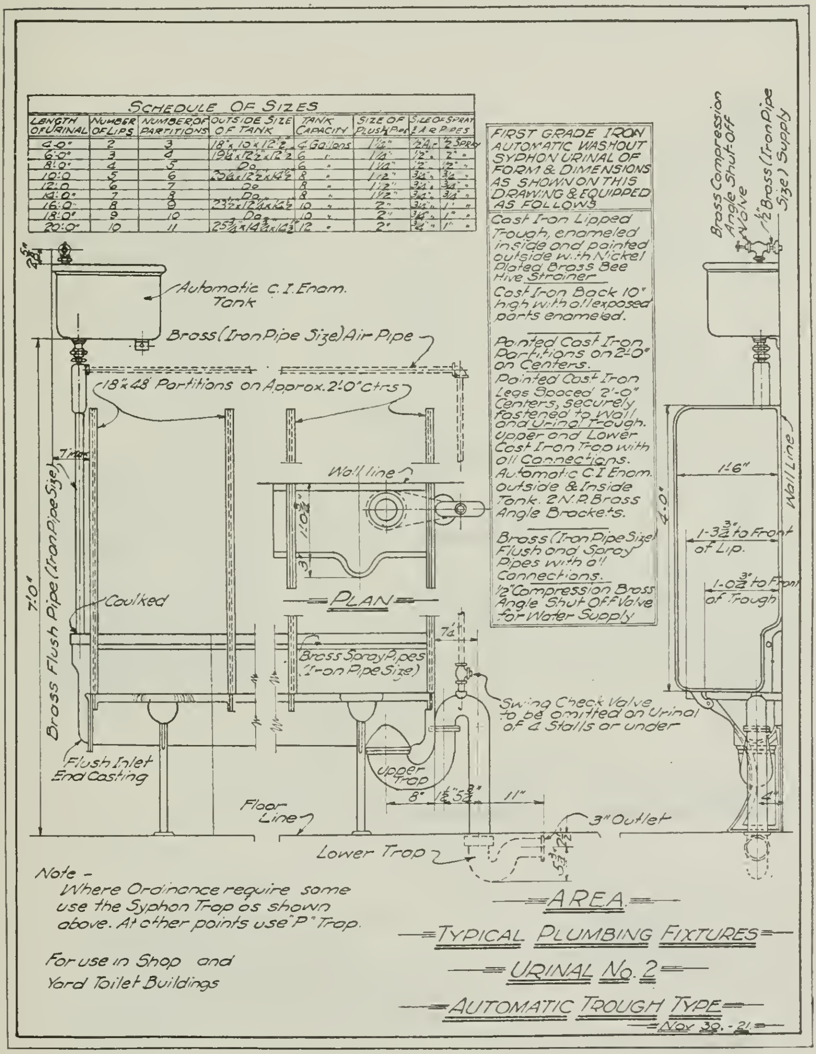


7/8" Plaster
7/8" Slate
Wall Line
Exp. Metal
Studs
Floor Line
6" Appx.
3'-0"
4'-0"
PLAN
Scale 1/2" = 1'-0"
FOR CONC. FLOOR & BASE
FOR TERRAZZO FLOOR & BASE
DETAIL OF BASE & SETTING FOR WALL SLATE
Scale 1 1/2" = 1'-0"
Note.-
Where Tanks are not used, slate at rear may be reduced to same height as slate at sides.
Top of slate at rear
1 1/4" Galv. Iron Pipe (Inside Diam)
Note -
Pipe Railing, Pipe Legs, Pipe Fittings, Slate Clips and Connections to be galvanized iron unless otherwised called for
Provide and install one nickle plated substantial paper holder for each stall
Provide and install one Coat Hook
All slate used in stall construction to be black ribbon slate
1'-0"
5'-0"
3'-0"
5'-6" Wall Slate
6"
1 1/4" Galv. Iron Pipe (Inside Diam)
Floor Line
SIDE ELEVATION
FRONT ELEVATION
A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSET STALL No. 1
SLATE TYPE WITHOUT DOORS
Nov. 30, 1921
For use in Shop and Yard Toilet Buildings and Ware Room Portion of Freight Houses


Note:-
Where Tanks are not used Slate at rear may be reduced to same height as Slate at sides.
Top of Slate at rear
Wall Line
Partitions 3'.0" on Ctrs.
1¼" Galv. Iron Pipe (Inside Diam.)
PLAN FOR END ENTRANCE
Scale ½" = 1'.0"
1¼" Galv. Iron Pipe (Inside Diam.)
"A" Grade Yellow Pine Doors
1¼" Gal. Iron Pipe (Inside Dia.)
Floor Line
DOOR DETAILS
Scale 1½" = 1'.0"
ELEVATION OF HANGING STILE FOR 2 OR MORE DOORS
ELEVATION OF END ENTRANCE
Scale ½" = 1'.0"
⅞ Plaster
⅞ Slate
Wall Studs
Exp. Metal
Approx.
Floor Line
HARDWARE FOR ONE DOOR
Spring Hinges to hold open.
Indicating Door Bolt.
Door Strike.
Coat Hook.
1¼" Galv. Iron Pipe (Inside Diam.)
Floor Line
ELEVATION FOR SIDE ENTRANCE
Scale ½" = 1'.0"
Wall Line
Face of Base where Slate does not occur
1" Cove
FOR CONCRETE FLOOR & BASE
FOR TERRAZZO FLOOR & BASE
DETAIL OF BASE & SETTING FOR WALL SLATE
Scale 1½" = 1'.0"
Note -
All Slate used in stall construction to be black ribbon slate.
Pipe railing, pipe legs, pipe fittings, slate clips and connections to be galv. iron unless otherwise called for.
Provide and install one nickel plated substantial paper holder.
PLAN FOR SIDE ENTRANCE
Scale ½" = 1'.0"
— A. R. E. A. —
— TYPICAL PLUMBING FIXTURES —
— CLOSET STALL No. 2 —
— SLATE TYPE WITH DOORS —
— Nov. 30, 21 —
For use in Office Buildings and Important Stations

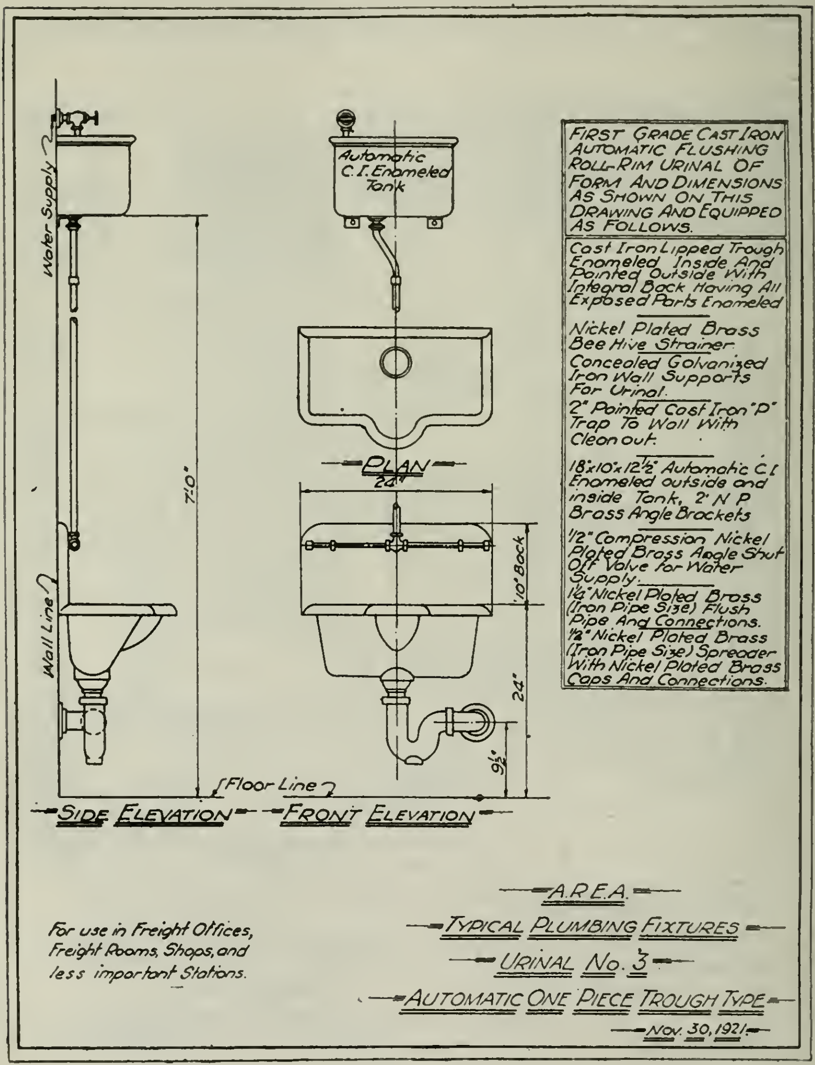

PLAN FOR END ENTRANCE
Scale ½" = 1'-0"
Cut on this line for one stall
Yellow Pine
3 Bracing L's 2½"x2½"x3/16
ELEVATION FOR SIDE ENTRANCE
Scale ½" = 1'-0"
¾"x3¼" D.M.B.& C.B. Ceiling Yellow Pine
Floor Line
PLAN FOR SIDE ENTRANCE
Scale ½" = 1'-0"
"A" Grade Yellow Pine
ELEVATION OF HANGING STILE FOR SIDE ENTRANCE STALLS
Scale 1½" = 1'-0"
HARDWARE FOR 1 DOOR
2 - Door Hinges.
1 - Indicating Door Bolt
1 - Door Strike
1 - Coat Hook.
Ctrsk Holes for ¼"x1¾" Wood Screws
¼"-¼ Round
Left Hand Thread
Right Hand Thread
SECTION "A-A"
¼" Exp. Anchor Bolts
DETAIL OF ADJUSTABLE PIPE LEGS FOR STALLS
Scale 3" = 1'-0"
Ctrsk Holes on inside for ¼"x1½" wood Screws
Bracing Angles
DETAIL OF 2½"x2½"x3/16"x ½" LONG
Scale 1½" = 1'-0"
ELEVATION OF HANGING STILE FOR END ENTRANCE STALLS
Note -
All woodwork to be painted two coats of approved paint as directed
Provide and install 1-Nickel Plated Substantial Paper Holder
For Use in Freight Offices and Rooms, Shops, and Less Important Stations.
A.R.E.A.
TYPICAL PLUMBING FIXTURES
CLOSET STALL No. 3
WOOD TYPE WITH DOORS
Nov. 30, -21


Water Supply
2"
9"
10"
2'-0"
PORCELAIN FLOOR TYPE URINAL OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS.
Integral Urinal & Drip Receptor Glazed on Inside and all exposed outside Parts
Porcelain Floor Slab Glazed on all exposed Outside Parts
Nickel Plated Cast Brass Waste Outlet Connections With Galvanized Iron Drain Trap of an Approved Design.
Porcelain Strainer
9"x15"x10"-2 Gal. Enam C.I. Automatic Flushing Tank Provided with 4 Screw Holes at the top for fastening to Wall.
Nickel Plated Brass Flush & Spreader Pipes With Nickel Plated Brass Flush Connections
Nickel Plated Brass Compression Angle Shut-Off Valve For Water Supply.
1'-8"
1'-4"
1'-3½"
12"
1'-2"
1'-9¾"
9½"
Floor Slab
10"
PLAN
1'-3½"
1'-2"
7'-0"
4'-0"
24"
Floor Line to Pitch to Urinal
8½"
1½" Finished Fl. Line
Center Of Outlet
Waste 2" I. P.
Cast Iron Comb Drum Trap Outlet Tapped for 2" I. P.
5¾"
1'-0"
1'-8"
SECTION
ELEVATION
A.R.E.A.
For use in Office Buildings and Important Stations.
TYPICAL PLUMBING FIXTURES
URINAL No. 1
FLOOR TYPE
Nov 30 - 21

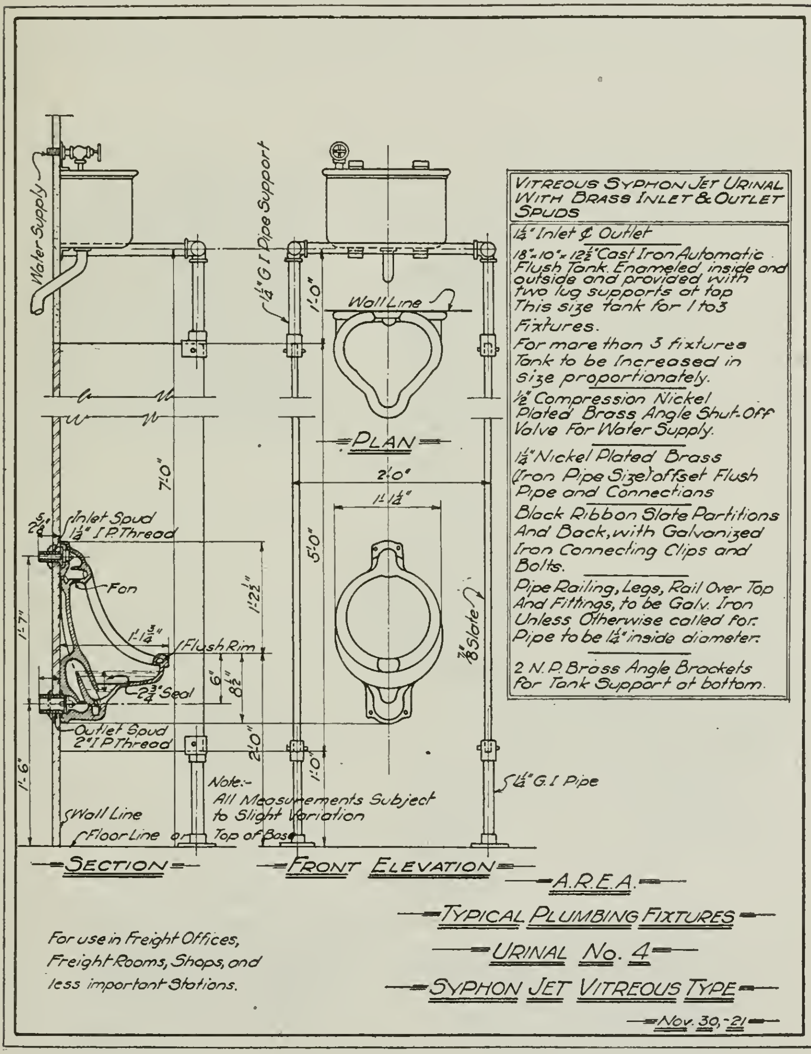

SCHEDULE OF SIZES

LENGTH OF URINAL	NUMBER OF LIPS	NUMBER OF PARTITIONS	OUTSIDE SIZE OF TANK	TANK CAPACITY	SIZE OF FLUSH PIPE	SIZE OF SPRAY & AIR PIPES	
4'-0"	2	3	18"x10"x12½"	4 Gallons	1¼"	½ Air	½ Spray
6'-0"	3	4	19¾"x12½"x12½"	6 "	1¼"	½" "	½" "
8'-0"	4	5	Do	6 "	1¼"	½" "	½" "
10'-0	5	6	23¼x12½x14½	8 "	1½"	¾" "	¾" "
12'-0	6	7	Do	8 "	1½"	¾" "	¾" "
14'-0"	7	8	Do	8 "	1½"	¾" "	¾" "
16'-0"	8	9	23½x12¼x16½	10 "	2"	¾" "	1" "
18'-0"	9	10	Do	10 "	2"	¾" "	1" "
20'-0"	10	11	25¾x14¾x16½	12 "	2"	¾" "	1" "

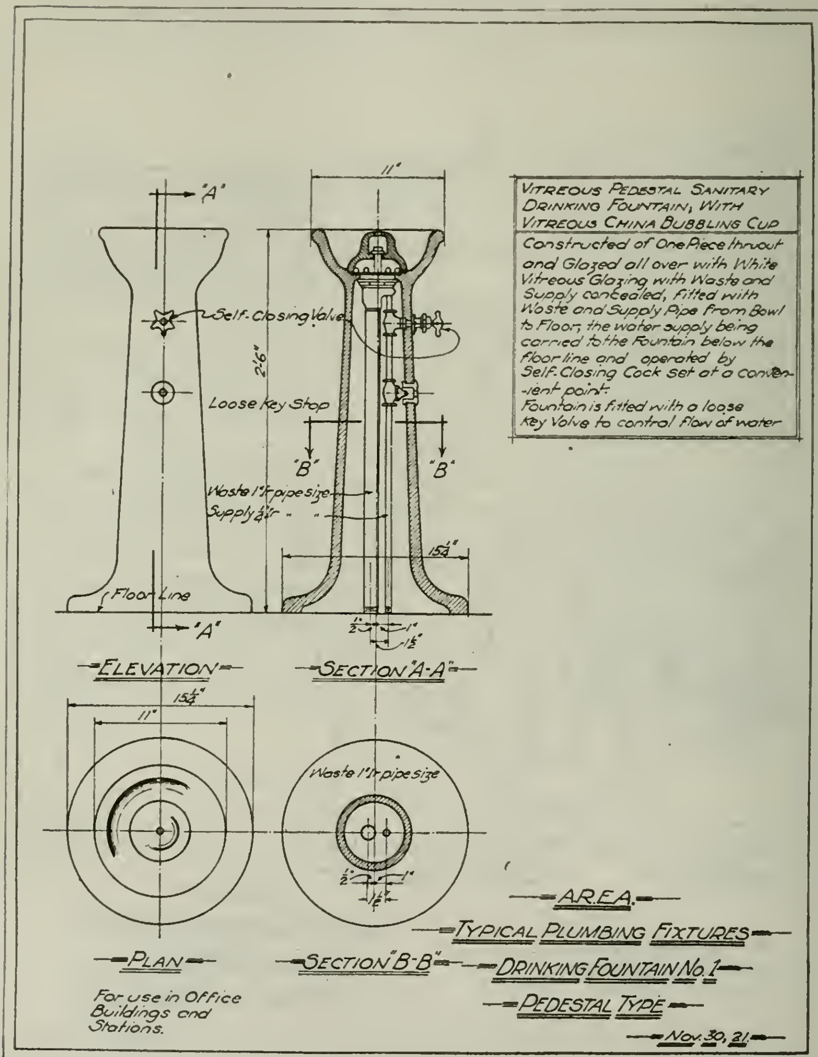
FIRST GRADE IRON AUTOMATIC WASHOUT SYPHON URINAL OF FORM & DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS
Cast Iron Lipped Trough, enameled inside and painted outside with Nickel Plated Brass Bee Hive Strainer
Cast Iron Back 10" high with all exposed parts enameled.
Painted Cast Iron Partitions on 2'-0" on Centers.
Painted Cast Iron Legs Spaced 2'-0" Centers, securely fastened to Wall and Urinal Trough.
Upper and Lower Cast Iron Trap with all Connections.
Automatic C.I. Enam. outside & Inside Tank. 2 N.P. Brass Angle Brackets.
Brass (Iron Pipe Size) Flush and Spray Pipes with all Connections.
½" Compression Brass Angle Shut Off Valve for Water Supply
Automatic C.I. Enam. Tank
Brass (Iron Pipe Size) Air Pipe
18"x48" Partitions on Approx. 2'-0" Ctrs
Wall line
PLAN
Brass Spray Pipes (Iron Pipe Size)
Brass Flush Pipe (Iron Pipe Size)
7'-0"
Caulked
Flush Inlet End Casting
Floor Line
Swing Check Valve to be omitted on Urinal of 4 Stalls or under
Upper Trap
Lower Trap
3" Outlet
Brass Compression Angle Shut-Off Valve
½" Brass (Iron Pipe Size) Supply
Wall Line
1'-6"
4'-0"
1-3¾" to Front of Lip.
1-0¾" to Front of Trough
Note - Where Ordinance require same use the Syphon Trap as shown above. At other points use "P" Trap.
For use in Shop and Yard Toilet Buildings
AREA
TYPICAL PLUMBING FIXTURES
URINAL No. 2
AUTOMATIC TROUGH TYPE
Nov 30.-21.

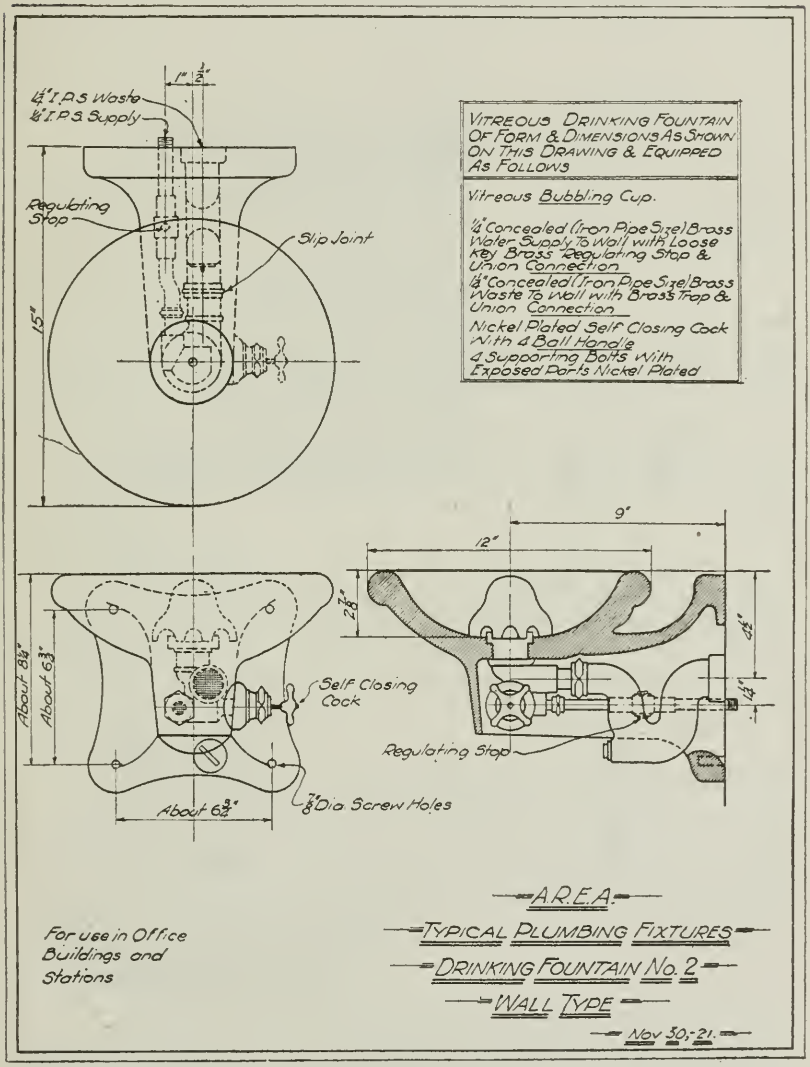


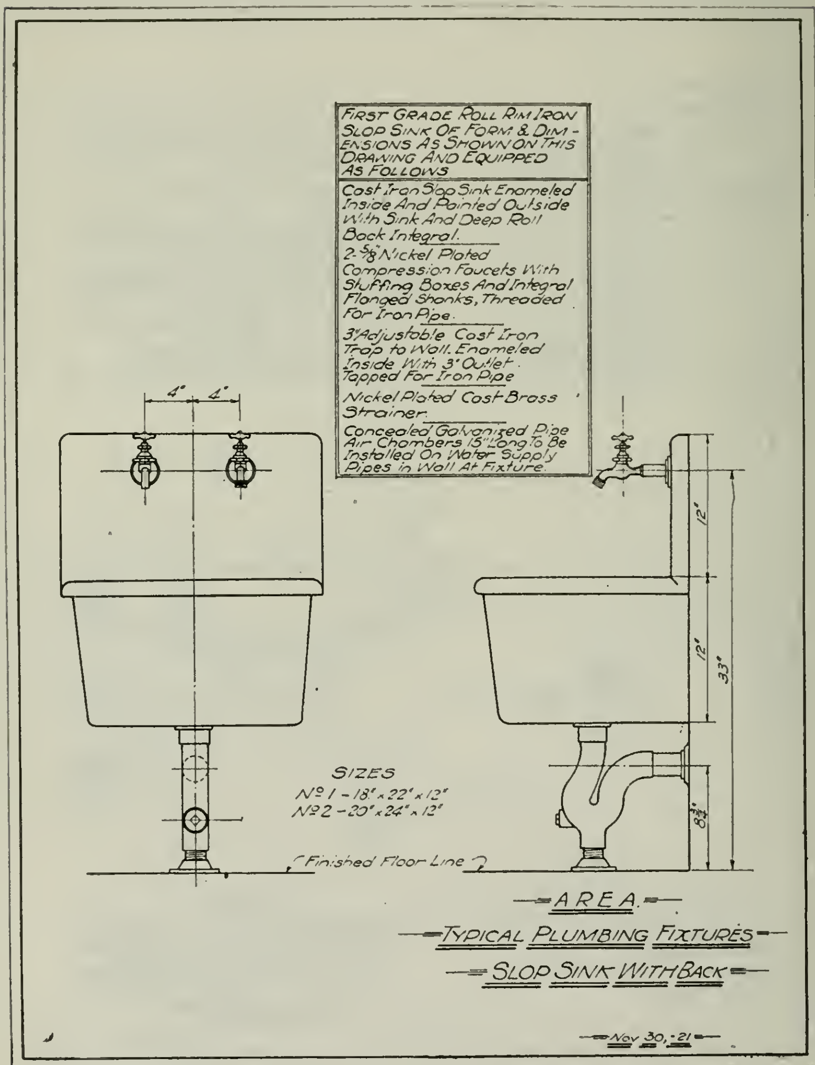
Water Supply
Automatic C.I. Enameled Tank
7'-0"
Wall Line
PLAN
24"
10" Back
24"
9½"
Floor Line
SIDE ELEVATION
FRONT ELEVATION
FIRST GRADE CAST IRON AUTOMATIC FLUSHING ROLL-RIM URINAL OF FORM AND DIMENSIONS AS SHOWN ON THIS DRAWING AND EQUIPPED AS FOLLOWS.
Cast Iron Lipped Trough Enameled Inside And Painted Outside With Integral Back Having All Exposed Parts Enameled
Nickel Plated Brass Bee Hive Strainer.
Concealed Galvanized Iron Wall Supports For Urinal.
2" Painted Cast Iron "P" Trap To Wall With Cleanout.
18"x10"x12½" Automatic C.I. Enameled outside and inside Tank, 2" N P Brass Angle Brackets
½" Compression Nickel Plated Brass Angle Shut Off Valve for Water Supply.
1¼" Nickel Plated Brass (Iron Pipe Size) Flush Pipe And Connections.
½" Nickel Plated Brass (Iron Pipe Size) Spreader With Nickel Plated Brass Caps And Connections.
For use in Freight Offices, Freight Rooms, Shops, and less important Stations.
A.R.E.A.
TYPICAL PLUMBING FIXTURES
URINAL No. 3
AUTOMATIC ONE PIECE TROUGH TYPE
Nov. 30, 1921


Water Supply
1¼" G.I. Pipe Support
1'-0"
Wall Line
=PLAN=
2'-0"
1'-1½"
7'-0"
5'-0"
⅞" Slate
Inlet Spud
1¼" I.P. Thread
Fan
1'-1¾"
Flush Rim
1'-2½"
6"
8½"
2¾" Seal
Outlet Spud
2" I.P. Thread
1'-7"
1'-6"
2'-0"
1'-0"
1¼" G.I. Pipe
Note:-
All Measurements Subject to Slight Variation
Wall Line
Floor Line or Top of Base
=SECTION=
=FRONT ELEVATION=
VITREOUS SYPHON JET URINAL WITH BRASS INLET & OUTLET SPUDS
1¼" Inlet & Outlet
18"×10"×12½" Cast Iron Automatic Flush Tank. Enameled inside and outside and provided with two lug supports at top
This size tank for 1 to 3 Fixtures.
For more than 3 fixtures Tank to be Increased in size proportionately.
½" Compression Nickel Plated Brass Angle Shut-Off Valve For Water Supply.
1¼" Nickel Plated Brass (Iron Pipe Size) offset Flush Pipe and Connections
Black Ribbon Slate Partitions And Back, with Galvanized Iron Connecting Clips and Bolts.
Pipe Railing, Legs, Rail Over Top And Fittings, to be Galv. Iron Unless Otherwise called for. Pipe to be 1¼" inside diameter.
2 N.P. Brass Angle Brackets for Tank Support at bottom.
=A.R.E.A.=
=TYPICAL PLUMBING FIXTURES=
=URINAL No. 4=
=SYPHON JET VITREOUS TYPE=
=Nov. 30,-21=
For use in Freight Offices, Freight Rooms, Shops, and less important Stations.

A


"A"
Self-Closing Valve
Loose Key Stop
Floor Line
"A"
11"
2'6"
"B"
"B"
Waste 1¼" pipe size
Supply ¼" "
15¼"
½" 1" 1½"
ELEVATION
SECTION "A-A"
15¼"
11"
Waste 1¼" pipe size
½" 1" 1½"
PLAN
SECTION "B-B"
For use in Office Buildings and Stations.
VITREOUS PEDESTAL SANITARY DRINKING FOUNTAIN, WITH VITREOUS CHINA BUBBLING CUP
Constructed of One Piece thruout and Glazed all over with White Vitreous Glazing with Waste and Supply concealed, fitted with Waste and Supply Pipe from Bowl to Floor; the water supply being carried to the Fountain below the floor line and operated by Self-Closing Cock set at a convenient point.
Fountain is fitted with a loose Key Valve to control flow of water
AREA
TYPICAL PLUMBING FIXTURES
DRINKING FOUNTAIN No. 1
PEDESTAL TYPE
Nov. 30, 21


1¼" I.P.S Waste
¼" I.P.S. Supply
1"
½"
Regulating Stop
Slip Joint
15"
VITREOUS DRINKING FOUNTAIN OF FORM & DIMENSIONS AS SHOWN ON THIS DRAWING & EQUIPPED AS FOLLOWS
Vitreous Bubbling Cup.
¼" Concealed (Iron Pipe Size) Brass Water Supply To Wall with Loose Key Brass Regulating Stop & Union Connection
1¼" Concealed (Iron Pipe Size) Brass Waste To Wall with Brass Trap & Union Connection
Nickel Plated Self Closing Cock With 4 Ball Handle
4 Supporting Bolts With Exposed Parts Nickel Plated
9"
12"
About 8¼"
About 6¾"
Self Closing Cock
About 6¾"
⅞" Dia. Screw Holes
Regulating Stop
For use in Office Buildings and Stations
A.R.E.A.
TYPICAL PLUMBING FIXTURES
DRINKING FOUNTAIN No. 2
WALL TYPE
Nov 30,-21.



First Grade Roll Rim Iron Slop Sink Of Form & Dimensions As Shown On This Drawing And Equipped As Follows
Cast Iron Slop Sink Enameled Inside And Painted Outside With Sink And Deep Roll Back Integral.
2-5/8 Nickel Plated Compression Faucets With Stuffing Boxes And Integral Flanged Shanks, Threaded For Iron Pipe.
3" Adjustable Cast Iron Trap to Wall. Enameled Inside With 3" Outlet. Tapped For Iron Pipe
Nickel Plated Cast Brass Strainer.
Concealed Galvanized Pipe Air Chambers 15" Long To Be Installed On Water Supply Pipes in Wall At Fixture.
4"
4"
12"
12"
33"
8¾"
Sizes
No 1 - 18" x 22" x 12"
No 2 - 20" x 24" x 12"
Finished Floor Line
Area.
Typical Plumbing Fixtures
Slop Sink With Back
Nov 30, -21

SPECIFICATIONS FOR RAILWAY BUILDINGS

SECTION 11

Heating

(a) Hot Water Heating System, Two-Pipe Gravity.
(b) Steam Heating System, One-Pipe Gravity.
(c) Steam Heating System, Two-Pipe Gravity.

1. General (Water and Steam).

Heating work to be done under this contract shall consist of furnishing and installing a heating system complete as hereinafter described.

2a. Checking of Drawings. (Water or Steam.)

The Contractor shall check all drawings and must report all discrepancies before starting the work. No allowances will be made by the Company for errors or discrepancies discovered by the Contractor after the work has been started.

3a. Laying Out Work. (Water or Steam.)

All dimensions on drawings shall be verified at the site of the work by the Contractor and he shall assume all responsibility for their accuracy.

4a. System (Water).

The system of heat transmission to be used will consist of a two-pipe gravity hot water heating system, complete in all details, whether specifically mentioned or not.

Direct radiation to be used at all points and in such units as are shown on drawings.

4b. System (Steam).

The system of heat transmission to be used will consist of a one-/two- pipe low pressure steam heating system, complete in all details, whether specifically mentioned or not, steam being circulated to all parts of the building and condensation brought back to the boiler under gravity conditions. No mechanical device of any kind shall be used to aid circulation. Direct radiation is to be used at all points and in such units as are shown on drawing.

5a. Boiler (Water).

The Contractor shall furnish and install in boiler room where shown on drawing....................one (1)............................, as manufactured by the..or equal.

The boiler shall be provided with all necessary castings, doors, shaking grates, firing and cleaning tools, etc., ready for operation.

Grates shall be furnished to enable................to be used as fuel.

The Contractor shall also furnish the following:

One high duty direct contact thermometer for registering the temperature of water; this thermometer to have white enamel face and red liquid. One altitude gauge for registering the proper height of the water in the expansion tank.

One "Syphon" water regulator or equal of required size for correct temperature control.

The Contractor shall also make necessary connection to the water supply where found in the building and shall provide draw-off valves to enable the system to be drained.

The boiler shall be covered with a covering of approved make, as outlined in paragraph No. 17 of these specifications, unless otherwise specified.

This boiler is to be tested for any defects in castings before any covering is applied. Boiler shall be installed in accordance with manufacturer's specifications.

5b. Boiler (Steam).

The Contractor shall furnish and install in boiler room where shown on drawing...............one (1)...................................... as manufactured by the..or equal.

The boiler shall be provided with all necessary castings, doors, shaking grates, firing and cleaning tools, etc., ready for operation.

Grates shall be furnished to enable................to be used as fuel. The boiler shall be furnished with approved type of steam gauge with syphon safety valve of sufficient capacity to take care of boiler, also water gauge and gauge cocks.

For correct regulation, this boiler shall be equipped with a "Syphon" steam regulator or equal.

The Contractor shall also make necessary connection to the water supply where found in the building, and shall provide draw-off valves to enable the system to be drained.

The boiler shall be covered with a covering of approved make as outlined in paragraph No. 17 of the specifications, unless otherwise specified. The boiler is to be tested for any defects in castings before any covering is applied.

Boiler shall be installed according to manufacturer's specifications.

6. Breeching. (Water or Steam.)

This boiler shall be connected to chimney by a smoke breeching of No............gauge black iron, provided with necessary dampers and cleanout openings. These cleanout openings shall be of ample size and they shall be so arranged that the entire length of the breeching can be cleaned without dismantling same.

This breeching shall be of the required size and shall be painted both inside and outside with two coats of asphaltum varnish. This breeching shall be covered as specified in paragraph No. 17 of these specifications.

The Contractor shall support this breeching in a substantial manner. Where the breeching enters the chimney, it shall be increased in area at least ten (10) per cent.

Breeching shall be installed in such a manner as to maintain a minimum distance between nearest wall and breeching of eighteen (18) inches.

7a. Piping System (Water).

The system of piping to be used in this installation will be what is known as a two-pipe system with $\genfrac{}{}{0pt}{}{\text{basement}}{\text{overhead}}$ supply main and $\genfrac{}{}{0pt}{}{\text{up}}{\text{down}}$ feeds to all radiators. All piping is to be supported in a substantial manner.

Whenever possible, the piping is to be arranged in such a manner that the first radiator on the supply circuit will be the last on the return circuit. The system shall be provided with vents and drains at all points where required.

The supply and return piping is to be arranged in such a manner as to allow for proper circulation to all parts of the system without crowding or forcing.

All piping exposed in the building, with the exception of that in the boiler room, and where same is subjected to low temperatures, shall remain uncovered. All piping not exposed to public view, such as where located in boiler room, attic space, basement, concealed in walls, or exposed to low temperatures, shall be covered, as outlined in paragraph No. 16 of these specifications. Piping is to be concealed unless otherwise specified. Concealed piping is to be tested for leaks and defects before covering is applied.

Contractor shall ream the ends of all pipes used in connection with this installation, so that the flow will not be restricted.

No control valves are to be installed on supply or return mains or radiators, unless otherwise specified. Radiators requiring venting shall be equipped with air valves of the lock and shield compression type.

7b. Piping System (Steam).

The system of piping to be used in this installation will be a $\genfrac{}{}{0pt}{}{\text{two}}{\text{one}}$ pipe system with $\genfrac{}{}{0pt}{}{\text{overhead}}{\text{basement}}$ supply main and $\genfrac{}{}{0pt}{}{\text{down}}{\text{up}}$ feeds to all radiators. All piping is to be supported in a substantial manner.

The system is to be provided with vents and drips at all points where required.

Care shall be taken when laying out piping system, that the condensation shall flow in the same direction as the steam and the use of a wet return to the boiler is to be avoided wherever possible.

The piping is to be arranged in such a manner as to allow for proper circulation to all parts of the system without crowding or forcing.

All piping exposed in the building, with the exception of that in the boiler room and where subjected to low temperatures, shall remain uncovered. Piping not exposed to public view, such as where located in boiler room, attic space, basement, concealed in walls or exposed to low temperatures, shall be covered as outlined in paragraph No. 16 of these specifications. Contractor shall ream the ends of all pipes used in connection with this installation so that the flow will not be restricted.

Steam shall be taken from the boiler into a main leader and circulated through the building by means of supply mains. At each point where a supply main is taken off the main header, a control valve shall be installed.

Returns shall be brought back to a manifold header, which in turn shall be connected to the boiler. At each point where a return main is connected to the manifold header, a control valve shall be installed.

At the end of each supply and return main or where same drops to a lower level, an automatic vent shall be installed, so located that it can be inspected.

All concealed piping is to be tested for leaks and defects before covering is applied.

8. Expansion Tank. (Water.)

Contractor shall furnish and install in most suitable location, or as indicated on drawing, one..............Expansion Tank................ gallons capacity.

Expansion tank shall be properly vented, care being taken that vent is installed in such a manner as to prevent syphonage.

The expansion pipe shall be connected to the return main in the most suitable location.

The overflow pipe from the expansion tank shall be installed so that it will discharge to the drain in the boiler room.

Expansion tank is to be arranged so that it will be circulating if deemed necessary.

All necessary supports, piping, valves and connections for expansion tank are to be provided and installed by this Contractor.

9. Radiators. (Steam or Water.)

All radiators used in connection with this installation shall be of the following type according to location in which placed.

Floor pattern ....or equal.
Wall pattern ....or equal.

Contractor shall state make of radiators he proposes to furnish and no substitution will be allowed from that mentioned in proposal.

10. Hangers for Radiators. (Steam or Water.)

All radiators of wall pattern shall be so supported as to thoroughly take care of expansion and contraction by means of the................. hanger as made by.....................................

The hangers shall be fastened to the walls in their respective locations by heavy expansion bolts firmly secured in the walls.

Should the design of the trim of the building be such that hangers cannot be fastened directly to the walls, this Contractor shall provide the necessary material to install hangers. Lumber used for this purpose shall conform to the trim of the building in all respects and be of neat finish.

11. Location of Radiators. (Water or Steam.)

The location of the radiators as shown on the drawing shall be construed as being approximately correct. Should conditions at the building prove such as to make any changes necessary in the location of the radiators, from that shown on the drawing, such change will not alter price agreed upon in contract.

12. Connections to Radiators. (Water or Steam.)

All connections to radiators shall be taken from the $\frac{\text{bottom}}{\text{top}}$ of the supply main by 45° fittings and the distance between the supply main and the center of the radiator connections and shall not be less than thirty (30") inches. All return connections from the radiators shall be taken in at the side or top of the return main.

13a. Valves on Radiator. (Water.)

Radiator control valves when specified, shall be on return connection of radiator only.

Valves to be used shall be what are known as the quick operating water radiator valves, with a one-sixteenth of an inch (1/16") hole drilled in the conical shell, to allow for a slight circulation in the event the valve is closed and thus prevent a possible freezing of the radiator. All valves shall have rough body and nickel plated trimmings equipped with union connections and hard wood handle unless otherwise specified.

Air valves are to be installed on radiators where required and shall be of the lock and shield compression type.

Contractor shall state make of radiator and air valves he proposes to install and no substitution will be allowed from that mentioned in proposal. Each radiator is to be equipped with a valve of approved make, on flow and return.

13b. Valves on Radiator. (Steam, Two-Pipe.)

Valves shall be of radiator type with rough body, nickel plated trimmings, union connections and hardwood handles, unless otherwise specified.

Valves to be equipped with hard rubber disc of...................... make or equal.

Each radiator and point of the system requiring venting are to be equipped with non-adjustable automatic air valves of approved make.

Contractor shall state make and type of radiator and automatic air valves he proposes to furnish and no substitution will be allowed from that mentioned in proposal.

13c. Valves on Radiator. (Steam, One-Pipe.)

Each radiator shall be equipped with a valve of approved make. Valves shall be of radiator type and with rough body and nickel trimmings, union connections and hard wooden handles, unless otherwise specified.

Valves to be equipped with hard rubber disc of .... make or equal.

Each radiator and points of the system requiring venting shall be equipped with automatic non-adjustable air valves of approved make.

Contractor shall state make and type of radiator and automatic air valves he proposes to furnish and no substitution will be allowed from that mentioned in proposal.

14. Support for Pipe. (Water or Steam.)

All piping shall be firmly and neatly secured with proper provision for expansion and contraction. The horizontal lines shall be hung on neat trapeze expansion hangers placed at proper intervals while all other lines shall be provided with suitable hangers, best adapted to the existing conditions to make a good appearing and substantial job.

Anchors shall be placed at points on lines to take care of the expansion from central points to ends. The use of perforated bar or strap hanger will not be permitted.

Contractor when submitting his layout for approval, shall submit details of all hangers for the approval of the Engineer.

15. Expansion and Contraction. (Water or Steam.)

The expansion and contraction of all supply and return mains must be taken care of in the design of the system. The use of the mechanical slip joint will not be permitted in connection with this installation.

16. Material to Be Used. (Water or Steam.)

All pipe used in connection with this installation shall be new, strictly genuine wrought iron pipe as made by the.............................. ....or equal.

Valves shall be of type made by............................or equal.

Fittings shall be of fine grained grey cast iron...................... make or equal, with threads clean cut, tapering and smooth.

Thread joints shall be iron to iron without the use of red lead or cement, all flanged fittings shall be made with...................padding or gaskets or equal.

Unions shall be of the Railroad pattern, metal to metal, no gaskets to be used.

On all pipe lines three inches (3″) and up, flanged fittings shall be used and below that threaded fittings shall be used.

All materials used in connection with this installation shall be the best of their respective kind, and be put together by skilled mechanics under competent supervision.

All piping to be insulated in connection with this heating system shall be covered with................covering as made by the................ ....or equal.

This pipe covering shall be of standard thickness with metal bands at ends and center of sections. Fittings shall be covered with plastic material of quality described below and shall also have canvas jackets.

All piping installed underground shall be covered and encased in conduits as called for.

No covering is to be applied on any piping exposed in portion of building used by public unless otherwise specified.

Contractor shall state make and grade of covering he proposes to furnish and no substitutions will be allowed from that mentioned in proposal.

17. Plastic Covering. (Water or Steam.)

The boiler and smoke breeching in the boiler room shall be provided with a plastic asbestos covering of the above make, unless otherwise specified. This plastic covering shall be applied first in the form of asbestos blocks 1½" thick and then with ½" thick hard finish of asbestos cement, neatly secured in place, followed by a canvas jacket neatly pasted on.

The covering on the smoke breeching shall be in the form or 1" asbestos blocks applied on ½" mesh black iron wire cloth with 1" "V" iron attached to form air space and fastened directly to the iron, with finishing coat of cement followed by canvas jacket neatly pasted on.

18. Insulation Through Walls, Floors and Partitions. (Water or Steam.)

Where pipes pass through floors or run through partitions galvanized iron sleeves with proper air space between the walls of the sleeves and the pipes shall be placed. Where they pass through bearing walls, sleeves of wrought iron pipe shall be used with proper provision for air space. At all points where sleeves are used, proper nickel plated floor and ceiling plates shall be used.

Contractor shall pay special attention that there shall be no ragged holes appearing where any pipes pass through walls or floors.

19a. Guarantee. (Water.)

This Contractor must guarantee the perfect operation of the system as heretofore described and indicated on drawings that it will be capable of warming the rooms in the building to the following temperatures, with the temperature of the water in the radiators not to exceed 170° F.

Room	Outside Temp.	Inside Temp.
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

That it will circulate freely, without crowding or forcing, to all parts of the system and should any defects appear in same within the course of one year of actual operation, the Contractor shall make good at his own expense.

If in the opinion of the Contractor the amount of radiation and size of boiler as set forth on the drawings is not sufficient to fulfill his guarantee, he shall state in his proposal, the amount of additional radiation and additional boiler capacity which in his judgment is necessary and quote prices for same.

Any omissions in these specifications or the drawings accompanying same, do not relieve the Contractor of his obligation to install the system complete in every respect to fulfill his guarantee.

19b. Guarantee. (Steam.)

The Contractor must guarantee the perfect operation of the system heretofore described and indicated on drawing, that it will be capable of warming the rooms in the building to the following temperatures with a steam pressure of from two (2) to five (5) pounds per square inch by gauge on the boiler and a drop in pressure in the piping not to exceed eight (8) ounces.

Room	Outside Temp.	Inside Temp.
....	....	....
....	....	....
....	....	....
....	....	....
....	....	....

That it will circulate freely to all parts of the system without crowding or forcing, and should any defects appear in same within the course of one year of actual operation, the Contractor shall make good at his own expense.

If in the opinion of the Contractor, the amount of radiation and size of the boiler as set forth on the drawing, is not sufficient to fulfill his guaranty, he shall state in his proposal, the amount of additional radiation and additional boiler capacity which in his judgment, is necessary, and quote price for same.

Any omissions in these specifications or on the drawings accompanying same, do not relieve the Contractor of his obligations to install the system complete in every respect and fulfill his guaranty.

The minimum amount of direct radiation which will be acceptable in the building will be..............square feet.

If the Contractor considers it necessary to deviate from the plans in order that his guaranty may be fulfilled, he may do so only upon the written permission from the Engineer.

20. Preliminary Tests and Cleaning. (Water or Steam.)

The Contractor shall make a thorough test of the plant to ascertain whether there are any leaks in the boiler, piping, etc., after completion, he shall also arrange to remove all sediment, rust and dirt out of the system. In order to do this, the boiler is to be operated for a period of not less than twenty-four (24) hours and during this operation, the boiler is to be blown off frequently until the water blown down from the boiler is reasonably clear.

21. Test. (Water or Steam.)

Upon notification from the Contractor, the Company shall within two weeks, make a test of the complete system, and it will be accepted only after test is satisfactory to the Company, all leaks and defects have been repaired and all conditions of these specifications have been fully and satisfactorily complied with. The Contractor shall furnish a complete set of written instructions neatly framed and glazed, covering the operation of the plant for reference purposes.

22. Completion. (Water or Steam.)

At the completion of the installation and its acceptance by the Company, the Contractor must give instructions as to the operation of the plant, showing in detail all points that require attention and turn same over to the Company. He shall also furnish for the Company's file, one complete set of tracings or VanDyke negatives on cloth, showing in detail, the complete installation.

23. Cleaning. (Water or Steam.)

At the completion of the work, the Contractor shall remove all construction equipment, scaffolding, staging, erection platforms, and all surplus material from the premises, leaving the building in a clean and acceptable condition. If any equipment, material or debris is not removed with sufficient promptness, the Company may remove it at the expense of the Contractor.

24. General Conditions. (Water or Steam.)

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all of the work is completed. The general conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

SPECIFICATIONS FOR RAILWAY BUILDINGS

SECTION 12

Stone Masonry and Cut Stone Work

1. **General**

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any or all classes of stone masonry and cut stone work herein specified, according to the class of building and as shown on the drawings.

2. **Description of Stone.**

All stone specified or shown on drawings shall be sound, durable, well seasoned, from quarries approved by the Engineer and each stone shall be laid on its natural bed. When required by the Engineer samples shall be furnished, same to be about four (4) inches by seven (7) inches by one (1) inch thick produced so that the large faces shall show the grain or rift of the stone, the finish specified to be indicated on the large faces and at least two of the edges to be rock face. Similar samples to be provided when select stock is required for certain positions in the building. Samples submitted are to be typical of the extremes which the Contractor proposes to furnish.

3. **Cutting and Setting Drawings.**

The Cut-Stone Contractor shall prepare and submit to the Engineer for his approval, when required, complete cutting and setting drawings (in triplicate) for all the cut-stone work in this contract. Such drawings shall show in detail sizes and dimensions of stones, the arrangements of joints and bondings, anchoring and other necessary details.

4. **Carving.**

All carving shall be done by skilled carvers from approved models.

5. **Cutting and Finish.**

All exposed faces shall be cut true. The stone shall be out full to the square with joints as required. The arrises shall be full and true. Beds, ends and tops shall be dressed straight and at right angles to the face unless otherwise shown. No patching or hiding of defects will be permitted and Lewis holes shall not be cut on exposed surfaces.

Washes shall be as steep as practical and drips shall be provided on all projecting stones and courses of sufficient depth to shed water.

Specially graded stone acceptable as to hardness, and colour, as per samples to be submitted shall be employed for grade course steps and all other positions exposed to direct wear. Steps shall be cut with a slight pitch to the front.

The finish on exposed surfaces, except rock face work, shall be hand tooled work not less than (10) cuts to the inch.

Where molded work is tooled, the tooling shall run in the direction of the molding and not across.

Rock face work shall have no projection exceeding two (2) inches. Edges shall be pitched to a straight line.

6. Lewis Holes.

Lewis holes shall be cut in all stones weighing more than three hundred (300) pounds. No Lewis or other holes shall come within two and one-half (2½) inches of the exposed face of the stone, unless the stone is less than five (5) inches thick.

7. Mortar.

Mortar for all stone work, except where otherwise specified shall be composed of one (1) part Portland Cement, one (1) part lime putty and two parts sand, the sand and cement to be mixed dry, then wet to proper consistency, and the lime putty added. If stone work is to be laid with colored mortar the following mixture shall be used: One part Portland Cement, two (2) parts sand, with lime paste added to make it work smoothly and colored with approved mortar color. No more mortar containing cement shall be mixed at any one time than can be used within thirty minutes after mixing. Retempering cement mortar which has begun to set will not be permitted. No mortar which has frozen shall be used on the work.

Portland Cement shall be in accordance with the A.R.E.A. Specification.

Sand and Lime specifications as given in Section 5 "Brickwork" shall apply to sand and lime for stonework.

8. Anchors and Dowels.

Proper provision shall be made for anchoring and doweling the stone.

Anchors and dowels shall be of the proper size and shape and thoroughly galvanized, or coated with asphaltum paint.

9. Setting.

All stone shall be thoroughly cleaned on all joints before setting. Mortar to be kept three-quarters (¾) inch from the face of the stone to allow for pointing. Splashing exposed faces of stone with mortar shall be avoided. All beds and vertical joints shall be of a maximum width of one-quarter (¼) inch unless otherwise indicated. The stone shall be set accurately, true to line and level by competent stone setters. Face stones shall be set on thoroughly wetted wooded wedges which are not to be removed until the building is cleaned and pointed. The ends only of all sills shall be set in a full bed of mortar, balance of sills to be left free until pointed.

10. Broken Coursed Ashlar.

The face stones shall be rock faced edges pitched to a straight line, shall have paralled beds and rectangular joints.

The beds and joints for six (6) inches back from face shall be dressed to lay not over one-quarter (¼) inch joint.

The stones need not be laid up in a regular course, but shall be laid level on their natural beds, shall be well bonded, having at least one header, extending entirely through the wall, for every ten square feet of face surface. Headers shall be placed so that they come half way between the header of the course above and below. No stone shall be less than six (6) inches thick, and no stone shall measure in its least horizontal dimensions less than nine (9) inches.

11. Boulder Masonry.

Where shown on the drawings, foundation walls shall be composed of stone of proper size and thickness. They shall be of fair shape, and spalled so that they will lay with good even bearings on the wall. All stones shall be laid in full beds of mortar, all interstices filled and all exposed faces neatly pointed. All work must be thoroughly done and well bonded. A header, extending entirely through the wall, shall be built in every eight (8) square feet of surface. Each header shall break joint with the headers in the courses above and below.

12. Protection.

Wherever necessary, all projecting individual stones or courses shall be protected against injury during the setting process by wooden covering, which shall be maintained in good and substantial condition until removed for the purpose of cleaning down the stone work.

13. Cleaning and Pointing.

The face of the stone work under this contract shall be thoroughly cleaned upon completion, such cleaning to be done with soap powder boiled in clean water and applied vigorously with stiff fibre brushes. If necessary, clean, sharp, fine white sand to be added to the soap and water mixture. The use of acids will not be permitted for cleaning the stone work.

All face joints shall be brushed out three-quarters (¾) inch in depth and pointed flush with mortar consisting of one part stainless cement, two parts clean white sand and sufficient cold lime putty to make as stiff a mixture as can be worked.

14. General Conditions.

All material entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

SPECIFICATIONS FOR RAILWAY BUILDINGS

SECTION 13

Clay Hollow Tile

1. General.

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment except as otherwise noted, necessary to entirely complete any or all classes of clay hollow tile work herein specified, according to the class of building, and as shown or implied on the drawings.

Provide and erect all hollow tile exterior and interior bearing walls of hard burned hollow tile, true and regular in size.

Tile to which plastering is to be applied shall have all faces scored with special dove tail scoring to present a good bond for the finish.

All sub-dividing, non-bearing partitions, where shown on plans, shall be of hollow partition tile.

2. Laying.

Tile in the exterior walls and interior bearing walls shall be load bearing tile laid to develop their full strength. No vertical or head joints shall be mortared through the wall, but a generous air space shall be left in the center of the walls by buttering the two edges of each tile either before or after it is set in the wall.

3. Mortar.

All mortar used for laying up the hollow tile shall consist of an approved Portland Cement and clean sharp sand in the proportion of one (1) part cement to three (3) parts sand, well mixed to a smooth, moderately stiff mortar. Cold lime putty not to exceed 10 per cent of cement by volume, will be allowed in the mortar.

4. Foundation Tiles.

Where so indicated on the drawings, the foundation walls from top of footings to the underside of first floor beams shall be constructed of hard burned foundation tile. Where columns or piers supporting heavy loads rest on the foundation walls, same shall be filled with concrete from footing to top of walls.

5. Sub-Dividing Partitions.

All partitions shall be started on the structural floor and be wedged against the floor above.

6. Jamb Tile.

Provide for all door and window openings where indicated, jamb tile with rabbitted openings to receive the door or window frame box. Fill well with mortar the space between the tile and the frame box to within one inch of stop bead and calk to stop bead with roofers cement or oakum to prevent the passage of air or moisture.

7. **Lintels.**

Openings not exceeding five (5) feet in clear span may be spanned with arch lintel tile or with regular tile reinforced with proper steel rods in the lower cells and filled solidly with stone concrete.

Openings over five (5) feet in clear span shall be spanned with reinforced concrete or with steel lintels faced with tile, as shown on drawings.

8. **Sills.**

Where called for by the drawings sills of special hollow sill tile shall be used. Special care must be taken to fill all joints so as to prevent moisture working through the same; wood sill of window frame to be set in heavy bed of roofers cement.

9. **Arch Openings.**

Build all arch openings shown on drawings—2—course row-lock hollow brick header arches, carefully laid on substantial centers. Arches shall spring from the hollow tile and must be well bedded on them.

10. **Columns and Piers.**

Construct columns and piers, so indicated, on hollow tile to sizes as shown. Where column finish is round, build the same of circular hollow tile column covering, filling the columns with concrete where the second story walls are supported by them. Square columns shall be built of the proper size hollow tile laid as indicated under "Laying."

11. **Floor Joist Bearings.**

Provide and set tile slabs one (1) inch thick under all floor joists as bearing plates for end construction tile.

12. **Wall Plates.**

Embed in cement grout into upper courses of wall at intervals of five (5) feet ¾" bolts projecting six (6) inches above the top of the wall to allow of plate being fastened down with washers and nuts.

13. **Floors.**

Floors shall be segmental arch, flat arch of hollow tile construction, as indicated on the drawings.

14. **Tile.**

Depth of hollow tile will be regulated by span and load to be carried, and as indicated on the drawings. All tile must be wet before concrete or mortar is placed to insure a proper bond.

15. **Centers.**

Centers must be of such size as to insure against deflecting, and must not be removed before the floor has properly set and under long spans a center line of supports must be maintained for at least three weeks after the floor has been completed.

16. Cleaning, Etc.

Upon completion of this work the Contractor shall repair all damaged tile, clear away all rubbish of every description leaving this part of the work clean and in perfectly good condition.

17. General Conditions.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all the work is completed, and accepted. The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

SECTION 14

Steel and Iron Work

1. General.

The Contractor shall furnish all labor, material, tools and equipment necessary to entirely complete the structural steel and iron work as herein specified and as called for on the drawings.

2. Design.

The design of steel or iron work required will be indicated on the drawings furnished by the Company and such details as are not shown on these drawings shall be detailed on the shop drawings to be furnished by the Contractor and approved by the Engineer before fabrication.

3. Erection.

In the erection of steel or iron work the Contractor shall take particular care that the material is not damaged by falling or from any other cause. All material shall be properly fitted together and any shop errors shall be corrected in a manner satisfactory to the Engineer. Light drifting will be permitted to draw parts together, but no drifting will be allowed to match up unfair holes. Such holes shall be reamed or drilled. All splices and field connections shall be securely bolted prior to rivetting. Rivets must be driven tight and no recupping or caulking will be allowed. Rivet heads shall be full and of uniform size. Rivets shall be uniformly and thoroughly heated and no burnt rivets shall be used. Loose rivets shall be cut out and re-driven and in removing such rivets care shall be taken that the surrounding metal is not injured.

Bolted connections may be used only where shown on plans or where approved by the Engineer. In case bolted connections are used the bolt heads must be drawn tight and lock nuts furnished where required.

4. Inspection.

All iron and steel work shall be subject to inspection at the shop by the Company's representative and no shipment shall be made previous to such inspection.

5. Shop Painting.

All surfaces inaccessible after assembling must be painted with a good quality of red lead paint before the parts are assembled. After work is finished at the shops it shall be cleansed of all loose scale and rust and thoroughly and evenly covered with one coat of red lead paint before shipping. All planned or turned surfaces must be coated with white lead and tallow.

6. Pipe Railing.

Contractor shall furnish and place wrought iron pipe railings as shown on drawings, both inside and outside of buildings. These railings shall be provided with standard railing fittings and floor flanges and where set on masonry shall be securely anchored with one-half inch by four inch (½" x 4") expansion bolts. Where they are attached to steel or iron work they shall be securely bolted, using lock nuts. Where they are attached to woodwork they shall be securely fastened with appropriate wood or lag screws or bolts.

7. Metal Sash and Doors.

All metal sash and doors shall be furnished of a make acceptable to the Engineer. They shall be set under the supervision of the manufacturers, subject to the acceptance of the Engineer, and shall be of such sizes and units as are shown on the drawings. Where so indicated on drawings, sash shall be provided with ventilator opening and locking device. Sliding doors shall be complete with track, etc., as noted in specifications for Hardware. Contractor shall furnish detail plans or all steel sash and doors as soon as possible, so that detailed masonry work dimensions can be determined.

8. Sash Operators.

Sash operators shall be supplied so that all ventilating sash may be operated from the floor. Where several units are to be operated together, as in the case of the monitor sash, the device shall be .... of the..........................type, worm gear, vertical rod and horizontal wheel, or a similar device of equal merit.

9. Fire Doors.

Fire doors called for on the drawings shall be automatic sheet metal fire doors as manufactured by the.................................... or equal. They shall be hung complete with all hardware and shall conform to the requirements of the National Board of Fire Underwriters.

10. Mill Type Doors.

Mill Type Doors called for on the drawings shall be metal framed with the hangers, hinges or other operating hardware fastened directly to the metal as manufactured by the.................................... or equal. They shall be hung complete with all necessary hardware under the supervision of the manufacturers and to the approval of the Engineer.

11. Ceiling Registers.

Contractor shall furnish and place ceiling registers as indicated on drawings. These shall include a damper operated by a chain or cord which shall extend to within 7 feet 6 inches of the floor.

12. General Conditions.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed.

The General Conditions as given in Section 1 of this specification shall be considered to apply with equal force to this section of the specification.

13. Steel Work.

All structural steel shall conform to the Specification known as "Common Standard 1011" for steel buildings and miscellaneous structures, as follows:

General

1. The Railroad Company will furnish either general plans or such other data as are required to define the size and general characteristics of the structure.

2. Upon receipt of these, the Contractor shall prepare detail plans in strict conformity therewith, complete sets of which shall be submitted in triplicate to the Railroad Company for approval.

3. These plans shall include:

(a) A stress sheet, which shall show a skeleton diagram, the dead and live load assumptions, the stresses, the net area of cross section, and the make-up of each member of the structure.

(b) An erector's diagram which shall show clearly the marking and position of each member of the structure.

(c) Detail shop drawings of all members and their connections.

4. Upon approval of these plans, but not before, work on the structure may be begun, and it is expressly provided that such approval in no way releases the Contractor from responsibility for drafting or shop errors.

5. After plans have been approved, alterations will be permitted only upon the written instructions of the Railroad Company.

6. Before shipment of material shall have begun, one complete set of plans on tracing cloth shall be furnished by the Contractor without extra charge.

7. All claims for royalties on patented devices used in any structure shall be paid by the Contractor.

8. Such persons as the Company may appoint shall have free access at all times to the working drawings and shops of the Contractor, for the purpose of examining the plans and inspecting the materials and mode of manufacture and construction.

Materials

9. All parts of the frame shall be of open-hearth steel; but cast iron or cast steel may be used for columns, column bases, and other details when specified by the Railroad Company.

10. All steel shall be made by the open-hearth process and shall conform to the following requirements:

	Medium Steel	*Rivet Steel*	*Cast Steel*
Maximum Phosphorus (Basic)...	.04%	.04%	.04%
(Acid) ..	.08%	.08%	.08%
Maximum Sulphur	.05%	.05%	.05%
Ultimate Tensile Strength, in lb. per square inch..............	60,000 to 68,000	46,000 to 54,000	65,000
Elastic Limit, in lb. per sq. in......	33,000	26,000	33,000
Minimum Elongation in 8 inches, in per cent..................	22	26	15
Minimum Reduction of Area, in per cent	37	26	20

11. In addition to above test, pieces cut from material three-fourths of an inch thick or less should bend to close contact when cold without showing signs of cracking, and rivet steel when nickel and bent 180 degrees around a bar whose diameter is equal to the thickness of the rod shall not break with a sudden square fracture, but most show a gradual break and a fine silky homogeneous fracture.

12. The tensile strength, elastic limit, and elongation shall be determined by loading to point of rupture a specimen of not less than one-half square inch in section and not less than one-fourth of an inch in thickness, cut and planed or turned from a full-size section to a uniform section at least 9 inches in length, on 8 inches of which the elongation will be measured. These test specimens shall be cut by the mill from finished material selected by the inspector, and shall be so selected that the different sizes and shapes in the order shall be as nearly represented as póssible.

No final tests will be made on specimens rolled especially for test pieces. Every melt, as well as every furnace heat from which material is furnished, must be represented by the tests.

A bending test shall be made with each tensile test, if required.

The Contractor must promptly furnish the inspector with copies of invoices of all materials shipped to fill these orders. Rejected material must not be shipped from mill to fill any orders.

13. Except where chilled iron is specified, castings shall be of tough gray iron with not over 0.10 per cent sulphur. They shall be true to pattern, out of wind and free from flaws and excessive shrinkage.

Tests shall be made on a round bar 1¼ in. in diameter and 15 in. long. The transverse test shall be made on a length of 12 in. with a load at the middle. The minimum breaking load so applied shall be 2,900 lb., with deflection of at least 1/10 in. before rupture.

14. Steel castings shall be free from injurious blow-holes, true to pattern, and of workmanlike finish.

Loads

15. Structure shall be proportioned for the following loads:

(a) The total dead load in the structure.

Roof loads may be assumed as follows:

Covering.

	Weight, Including Roof Trusses, Lb. per Sq. Ft. of Area
Corrugated Iron and Shingles	11
Slate	14
Tar and Gravel	14

For spans over 75 feet, add 4 pounds per square foot to above loads. In case the dead load as actually designed should exceed the estimated dead load by ten per cent, the roof trusses shall be recomputed, and dimensions changed accordingly.

In case material other than those mentioned above is to be used for covering the roof, the weight per square foot of the roof is to be given by the Railroad Company for computing the roof trusses and other members.

(b) A live load on the floors and roofs as follows:

Machine Shops and Foundries.

One hundred fifty pounds per square foot where light machines are to be used and building is free from any very great vibration. If vibration is to be great, or heavy machines are to be used, this load must be increased in accordance with each particular case.

Office Buildings.

Sidewalks in front of office buildings, 200 pounds per square foot.

First floor, 125 pounds per square foot.

Floors above first, 60 pounds per square foot.

Reduction of Live Loads for Columns: For buildings over five stories high these live loads may be reduced as follows:

For roof and top floor, no reduction.

For each succeeding lower floor, a reduction of 5 per cent of the assumed live load, until a reduction of 40 per cent is reached, which is to be used for all remaining floors, viz., this reduced load is to be used for the total floor area carried by the column.

The above specified system of loading is to be used with a minimum of 30,000 pounds for the lightest column.

Waiting Rooms, Concourses and Train Platforms.

125 pounds per square foot.

Freight Sheds.

250 pounds per square foot.

Warehouses and Storehouses.

A minimum of 250 pounds per square foot.

These loads to be increased if very heavy material is to be stored.

16. For buildings of all classes a vertical live load of 25 pounds per square foot on horizontal projection of roof and a horizontal wind

load of 30 pounds per square foot on vertical projection of roof, and a horizontal wind load of 30 pounds per square foot on the side or end of the building. This vertical live load to be increased in localities subject to extreme snowfall. Snow to be taken to suit local conditions.

17. In proportioning columns, provision must be made for eccentric loading.

18. Buildings, or parts of buildings, liable to be subject to loads not mentioned, such as line shafting, hoists, etc., must be properly designed for such additional loads.

Stresses

19. In calculating the stresses the following conventional distances shall be assumed:

Length of girders, center to center of end bearings, or center to center of columns.

Length of trusses, center to center of end bearings.

Depth of plate girders, back to back of flange angles where cover plates are used, and center to center of gravity of flange angles where cover plates are not used.

20. The greatest working stress, in pounds per square inch, shall be as follows:

Class A—Buildings, tank towers and other structures not subject to severe vibration or shock.

Class B—Machine shops, foundries, foot bridges and similar structures subject to heavy vibration.

Class C—Crane girders and columns, and similar structures subject to shock.

	Class A *Lb. per Sq. In.*	*Class B* *Lb. per Sq. In.*	*Class C* *Lb. per Sq. In.*
Tension.			
Shapes, main members, flanges of beams and girders......	16,000	14,000	12,000
Outside fiber of pins........	20,000	18,000	18,000
Compression.			
Short pieces, flanges of beams and girders	16,000	14,000	12,000
Columns, lengths under 40 radii of gyration..........	15,000	13,000	12,000
Columns, length over 40 radii of gyration	$16{,}200-57\frac{l}{r}$	$15{,}200-57\frac{l}{r}$	$14{,}200-57\frac{l}{r}$
Outside fiber of pins........	20.000	18,000	18,000
Bearing.			
Projection semi-intrados pins and rivets	20,000	20,000	20,000
For hand-driven rivets reduce 20 per cent.			

Shearing.

Rivets and pins.............	10,000	10,000	10,000
For hand-driven rivets reduce 20 per cent.			
Webs of plate girders.......	9,000	8,000	7,000

l = length in inches.
r = least radius of gyration in inches.

21. No compression member shall have a length greater than 45 times its least width, or 102 times its least radius of gyration, except a member of lateral or wind bracing systems, which may have a length of 140 times its least radius of gyration.

22. All members subject to stresses of both tension and compression shall be designed to sustain both stresses with eight-tenths of the smaller added to each.

23. For knee braces, sway braces and wind bracing, increased above stresses for shapes and plates, 30 per cent, but do not increase stresses for rivets.

24. For combined live, dead and wind stresses, increase the preceding unit stresses 30 per cent above live and dead load unit stresses.

25. Where steel work is liable to corrosion, as when exposed in foundry buildings, increase sections to suit conditions as specified by the Railroad Company.

26. Bolts when used in place of rivets shall be allowed only two-thirds of the above unit stresses.

27. All bed plates shall be of such dimensions that the greatest pressure per square inch, due to any or all causes, upon the masonry shall not exceed: Stone masonry, 300 lb.; concrete masonry, 250 lb.; brick work, 150 lb.

28. Where lateral bracing consists of a double system of cancellation the lateral stresses shall be assumed to be equally divided between the two systems.

29. All horizontal or inclined members must be proportioned to sustain the combined stresses due to direct compression or tension and to the weight of the members and their transverse loads, but the combined unit stress from these causes must not exceed the unreduced direct unit stress by more than 10 per cent.

30. All struts must be proportioned to resist the resultant due to an initial stress of 10,000 pounds on all rods attached to them whenever this is in excess of the maximum stress produced from other causes.

31. All "I" beams shall be proportioned by their moment of inertia.

32. No part of the web-plate shall be estimated as flange area in proportioning plate girders.

General Details

33. In general, strength and simplicity shall be the first consideration in design of any structure and any arrangements of members which introduce uncertainty or indeterminateness of stresses must be avoided.

34. Due regard must be paid to the neat and attractive appearance of the finished structure and details of an unsightly character will not be approved.

35. All connections and details shall be of sufficient strength to develop the full strength of the member unless otherwise allowed by the Railroad Company.

36. Roof trusses shall be spaced if possible at such distance apart as to allow of single shapes to be used for purlins. It is desirable to avoid trussed purlins.

36a. Trusses shall preferably be riveted structures. Heavy trusses of long spans which would be unwieldy in erection, or on account of field riveting, or for any other good reasons, may be designed as pin-connected structures.

36b. Main members of trusses shall be designed so that the neutral axes of intersecting members shall, if practicable, meet in a common point.

37. Trusses over 100 feet span on walls shall have expansion rollers.

38. Sway and wind bracing shall be introduced at such points as may be necessary to insure sufficient transverse and longitudinal strength and rigidity.

38a. Roof trusses shall be braced in pairs in the planes of their upper chords.

39. All stresses from sway or wind bracing shall preferably be carried to the foundation direct, but may be accounted for by bending in columns.

40. Wall anchors shall be provided at not less than five-foot intervals with all floor beams, girders, roof purlins, etc., which come near or in contact with the interior walls.

40a. Floor Beams.—May be rolled beams or plate girders; they shall preferably be riveted or bolted to the columns by means of connecting angles. Shelf angles or other supports may be provided for convenience during construction.

40b. Floor Joist.—Shall generally be rolled beams, and the ends shall be attached to the webs of floor beams and columns with angle connections.

41. Upper chords of trusses or rafters shall have symmetrical cross-section and shall preferably consist of two angles back to back.

42. All other compression members, except sub-struts, shall be composed of sections symmetrically placed. Sub-struts may consist of a single shape.

43. Purlins shall be attached to the rafters by clips with at least two rivets at each end of each purlin, except at expansion joints where bolts must be used.

44. Laced compression members shall be stayed at the ends by batten plates having a length not less than the depth of the member.

45. Rivets and bolts preferably should not be used in direct tension.

46. No rivet hole shall be closer to the edge of a plate than 1¼ inches, except in bars less than 2½ inches wide.

47. The effective diameter of the driven rivet shall be assumed the same as before driving.

48. In making deductions for rivet holes in tension members the holes shall be assumed one-sixteenth of an inch larger than the undriven rivet.

49. Tension members shall preferably be angles or shapes.

50. Angles in tension shall be connected by both legs or only one leg shall be considered as being effective.

51. Long laterals or sway-rods may be made of rods with sleeve nut adjustment.

52. No upset rod shall be less than five-eighths of an inch diameter. Sag rods may be as small as five-eighths inch.

53. All rods with screw ends must be upset. The area at root of thread in upset ends shall be greater than the area of the rod by at least 17 per cent.

54. Bed plates shall not be less than one-half inch thick.

55. Each column base or bearing plate shall be provided with two anchor bolts of not less than three-quarters of an inch in diameter, either built into the masonry or extending far enough into it to make it effective.

56. Stiffeners must be used at intervals equal to the depth of girder whenever the ratio of the unsupported depth of the web to its thickness exceeds fifty; also at points of concentrated loads.

57. The compression flange of girders shall be stayed against transverse buckling at distance not exceeding twenty times their width or proper reduction be made in the unit stresses in computing the size of the flanges.

58. Top flange of built beams shall have the same gross area as bottom flange when of the same cross-section.

59. No material less than one-quarter of an inch thick shall be used except for fillers, and no webs of girders shall be less than five-sixteenths of an inch thick. No angles smaller than 2 in. x 2 in. x ¼ in. shall be used.

60. Where two or more cover plates are used in the flanges of girders they shall be of equal thickness, or shall decrease in thickness outward from the angle; the cover plate shall not extend more than 5 inches, or eight times the thickness of plate, beyond the outer line of rivets. In cover plates more than 14 inches wide four lines of rivets shall be used. Where practicable, the bottom cover plate of the top flange must run the whole length of the girder.

61. Pitch of rivets shall not be more than 6 inches or more than sixteen times the thinnest plate connected, or less than three times the diameter of rivets.

62. Rivet holes of the following portions of the structure, in metal ½ inch thick or over, shall be punched to a diameter ⅛ of an inch smaller on the die side than the finished diameter of the hole, and shall afterwards be reamed to a diameter one-sixteenth of an inch larger than that of the cold rivet:

(a) Flanges of all plate girders.

(b) Main compression members.

(c) All field connections.

This clause does not apply to roof trusses, which shall be punched work only, unless otherwise specified.

63. The roller end in every truss shall be free to move longitudinally under changes of temperature, but it must be securely anchored against lifting or moving sideways. The fixed end in every case shall be rigidly secured so that no motion can take place in any direction.

64. All members must be straight between points of connection.

Workmanship

65. All workmanship must be first class in every respect.

66. All abutting surfaces of compression members, except flanges of plate girders, which must be fully spliced, must be planed or turned so as to insure even bearings.

67. In all cases where it is necessary to partially heat a steel member, the whole piece must be subsequently annealed.

68. Built members, when finished, must be true and free from twists, kinks, buckles, or open joints between component parts.

69. Rivet holes must be accurately spaced and exactly opposite each other.

70. Rivets must be of the best quality of rivet steel, must completely fill holes, and must have full heads. Rivets for field work must have full and perfect heads, with underside of head square to shanks, shanks must be of a uniform circular section throughout and cut square at end, and must be free from projections or imperfections which would prevent the head from fitting closely before rivet is driven.

71. Eye-bars shall be die-forged without welds.

72. Columns shall be designed to provide for effective connections of floor beams, girders and brackets.

The column splices shall be designed to resist the bending stresses, and so as to make the columns practically continuous for their whole length. Columns shall be preferably continuous over several stories, and the joints so arranged that the splices on all columns do not occur in the same story.

73. All surfaces inaccessible after assembling must be painted with a good quality of red lead paint before the parts are assembled. After work is finished at the shops, it shall be cleansed of all loose scale and rust, and thoroughly and evenly covered with one coat of red lead paint before shipping. All planed or turned surfaces must be coated with white lead and tallow.

74. Projecting members, liable to be bent or injured in transit, must be blocked with wood before shipment in such a way as to protect them from injury in handling.

75. All material must be thoroughly straightened before being laid off or worked in any way.

76. No sharp unfilleted angle will be allowed anywhere, and wherever plate or shape has been cut into, the fillets as well as the cut must be finished so that no sign of the punched or sheared edge remains.

77. In punched work the diameter of the die shall not be more than one-sixteenth of an inch greater than the diameter of the punch. Riveted work shall be assembled so that the punch sides shall come together.

78. Riveted members must have all parts well pinned up and drawn together before riveting up, so that when finished they will be free from open joints and the component parts will lie close on each other.

79. All rivets must be driven by machine where possible, and where not possible, pneumatic driven rivets will be preferred to hand rivets.

80. Wherever practicable, reaming must be done after all pieces which are to be fastened together by the same rivets have been assembled. If necessary to take the pieces apart for shipping or handling, the respective pieces reamed together must be so marked that they may be reassembled in the final setting up. No interchanging of pieces after reaming will be allowed.

All spliced members shall be put together in the shop, and the field rivet holes reamed to a fit while these members with their splice plates are in place.

81. All stiffeners must have a tight fit between upper and lower flanges of girders.

82. No material shall be rolled or work done before the Railroad Company has been notified to what mill or works, orders have been assigned and arrangements have been made for inspection.

83. Complete copies of mill orders and plans will be furnished to the inspector, and he must be notified in time to be on hand when work is begun on his orders.

84. The Contractor must furnish all facilities for inspecting the workmanship and testing the quality of all material furnished on the order at the mill or shop where the material is manufactured.

85. The Inspector must be given reasonable facilities to check the weights of finished members before shipment. Not more than 2½ per cent excess weight over figured weight will be paid for by the Railroad Company.

86. Wherever bolts are used in place of rivets the holes must be reamed true to size after work is assembled, the bolts must be turned to a driving fit and their threads reduced one-eighth of an inch in diameter under size of finished bolts. A small washer, one-eighth of an inch thick, must be used under nut.

87. In case of local building ordinances conflicting with these specifications in whole or in part, the requirements of such ordinances will take precedence over these specifications.

SPECIFICATIONS FOR RAILWAY BUILDINGS

SECTION 15

Marble and Tile Work

1. **General.**

The Contractor shall furnish all labor, materials, tools, scaffolding and equipment, except as otherwise noted, necessary to entirely complete any or all classes of marble or tile work herein specified, according to the class of building, and as shown or implied on the drawings.

2. **Description of Marble.**

All marble specified or shown on drawings shall be the best of their several kinds, carefully selected for color, marking and location in the work, and each piece shall be subject to the Engineer's approval or rejection.

Samples eight by twelve (8″x12″) inches in size of each kind of marble specified shall be submitted for the Engineer's approval. These samples shall be finished as specified for the work and there shall be separate samples for each finish.

The completed work shall be equal to the approved samples as to quality, color, markings and finish.

3. **Thickness.**

All marble shall be thick enough to be amply strong for its size and location and no slabs shall be less than seven-eighths (⅞) inch in thickness.

All returns of eight (8) inches or less projection shall be from stock of sufficient thickness to form solid angles without vertical joints, angle pieces may be cut with hand saw, provided the position of joints is not altered from that shown on drawings. All molded or ornamented members shall be from stock sufficiently thick to permit of the finished work being an exact reproduction of the models or drawings without flattening. Projecting angles throughout shall be slightly rounded to prevent the edges chipping.

4. **Setting and Anchoring.**

All slabs shall be set free from backing surfaces using brick furring on vertical surfaces, and other approved materials elsewhere. All bearing edges shall be bedded solidly and continuously their entire length and no material other than pure plaster of Paris and pure non-staining Portland cement shall be used in setting. Each piece of marble throughout the entire work shall be securely fastened in place with brass or bronze dowels, clamps and tees, which must be provided and used in ample numbers to make a rigid and permanent job. No tees shall be fastened to the marble or walls by cement or plaster only, but each must fit into a properly drilled seat, shaped to retain the setting mortar.

. In no case shall any metal fastening show on the exposed faces unless specially mentioned herein or shown on the drawings. Specially made metal fastenings shall be used where necessary, or as may be directed.

5. **Finish.**

The finishes to be given marble are as follows:

(a) All floors and floor borders, stair treads, risers and landings and door saddles are to be honed.

(b) All marble, except as noted in (a) above, to be highly polished.

6. **Joints.**

All joints shall be close, showing only a hair line and each piece of marble shall be worked to absolutely perfect edges. The exposed surfaces of all marble shall be worked to true planes so that abutting edges cannot be felt. Any surface dressing necessary to obtain these results shall be continued the full length and width of the piece affected, so that the dressing cannot be felt or seen, and this shall include any dressing required after the marble is set in place.

7. **Supports for Marble Work.**

The Marble Contractor shall provide and set all steel supports of every description required specially for the proper setting of his work. Wherever this special steel framing is supported on the framing furnished and set by others, the Contractor for the marble shall furnish to such other contractors, within a reasonable time, carefully prepared drawings showing all required framing connections in detail so that provision may be made for the proper construction of the work, without unnecessary cutting and drilling, but if such framing is already in place, the Contractor for the marble work shall do all cutting, fitting and drilling required to properly connect his work to such framing.

All steel supports furnished by this contractor shall be given three coats, one shop coat and two field coats, of approved paint.

8. **Floors and Floor Borders.**

Wherever floors, floor borders or panel divisions are specified or shown they shall be not less than seven-eighths (⅞) inch in thickness, and at all openings shall be increased in width to meet the door saddles or filling pieces, which take the place of saddles.

9. **Terrazzo (Monolithic).**

Floors are to be divided into panels, as indicated on the drawings. Wherever shown borders of different colored terrazzo are to be run, and panels are to be formed by strips of colored terrazzo.

Floors shall be composed of Portland cement and selected first quality chips of marble. Chips shall be of a reasonable uniform size, perfectly clean and uniformly distributed over the surface, and showing the greatest possible proportion of marble in the finished state.

Wherever terrazzo base is indicated it shall be of the height required above the floor, finished with a one (1) inch radius cove at the intersection with the floor.

10. Terrazzo (Tile).

All rooms so indicated on drawings shall have terrazzo tile floors and base as manufactured by................................or equal. The pressure used in the manufacture of all tile for the work shall not be less than 2500 lb. to the square inch. All tile shall be 12"x12" for the field and have a double border. All tile to be not less than one inch (1") in thickness. All rooms having terrazzo tile floors shall have a six-inch (6") terrazzo cove base as detailed. All doors shall have terrazzo plinths in connection with terrazzo base. Tile must be so made that their structure will be free from air bubbles, and when rubbed to a finished surface must present a solid body. No tile, the surface of which has been filled or otherwise treated after rubbing, shall be used. The tile shall be laid in a true and level plane at elevations shown on drawings, in a first class and workmanlike manner. Great care shall be taken to have all lines and spacings true and straight, and all joints of even width, not exceeding one-sixteenth (1/16") of an inch. Provide terrazzo thresholds at all doors in connection with terrazzo tile floors, unless thresholds of other materials are called for.

Tile shall be set on a bed of mortar composed of two (2) parts Portland cement and three (3) parts sand. Tile to be rammed to a solid and even bed, grouted and rubbed.

Before depositing bedding mortar, the entire surface shall be cleaned and well saturated with water to prevent too rapid absorption of water from bedding mortar.

After tile is laid and properly grouted, all tile floors shall be holystoned to reduce inequalities of surface. All tile for floors and base shall be made with marble chips of kind and color selected by the Engineer. Contractor shall submit samples of tile and setting plan for approval before getting out any work.

Contractor shall guarantee all terrazzo work for a period of one year after completion against defects of workmanship or material.

11. Marble for Floors.

Marble floors and floor borders shall be composed of marble tile not less than seven-eighths (⅞) inch in thickness, cut with full faces, sawn bed, and all edges rubbed to the exact size required.

Each piece of marble shall be set in full bed of Portland cement mortar, and when set, all joints shall butt and match perfectly and closely and shall be perfectly flush. All pieces shall be selected and located in the floor according to character of veinings and color.

12. Vitrified Tile.

(a) On Walls.—Tile for walls shall be salt glazed white tile laid in cement with hair line joints absolutely plumb and true without waves. Where trim of other material is not specified, the tile shall be returned into all riveals and soffits and the angle shall be formed of angle tile with corner rounded to a radius of about one (1") inch. Where tile wainscot is called for there will also be required a sanitary tile base eight (8″) inches high.

(b) Floor Tile.—To be hexagonal or other approved shapes of vitrified tile, set in cement mortar. Border of two (2″) inch square tile to be laid at the intersection of floor with base.

13. Beds.

The distance from the finished floor to the rough floor will be not less than two (2″) inches and this Contractor shall fill in on top of the rough floors to the desired line with concrete composed of one part Portland cement, two parts sand and four parts crushed stone or gravel to form bed for flooring material.

14. General Conditions.

All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer and no part of the work will be considered as finally accepted until all the work is completed and accepted.

The General Conditions as given in Section 1 of this specification shall be considered as to apply with equal force to this section of the specification.

Appendix B

ICE HOUSES AND ICING STATIONS

E. CHRISTIANSEN, *Chairman;* F. R. JUDD,
J. B. GAUT, C. W. RICHEY,
Sub-Committee.

This report of Sub-Committe on Ice Houses and Icing Stations is to be considered only a preliminary study on the subject; as a study should first be made of the various arrangements of ice houses and platforms handling natural and artificial ice, either crushed or cake, by both gravity and mechanical methods, and the many conditions which affect the type and arrangement. Ice houses and icing stations do not come in what might be called the "ornate" phase of building construction; but with a little study of proportion and arrangement the result—with the equipment in working order and ice delivered to storage, or from storage to trains. The entire layout moving smoothly—will reward the designer for his efforts.

Icing stations, while not a direct revenue producer, are a necessary facility in connection with the operation of some railways. A dollar well spent will be doubled by saving in operation. As an illustration: Assuming that the selected point for a station having a great amount of icing to be done in a limited amount of time, one could build a gravity system, the cheapest layout known. From an economical operating standpoint this may not be the proper thing to do, as gravity is a slow method of handling ice. There are now on the market many good mechanical appliances which are very effective in handling ice speedily, both crushed and cake, which are flexible to many conditions. In connection with both of these methods of handling ice, there is an element which must be always taken into consideration, namely, that the ice must be always under control, as, once it gets away, there is no way to regain control of it and the result is collision of the cakes, broken ice and loss of money.

Ordinarily, there is not enough thought given to arrangement of rooms and machinery. Poor arrangement will increase the cost of filling a house as much as five or more per cent. per ton. This also applies to the movement of ice from storage to cars. Some consider the number of rooms an essential point; the larger the number of rooms, the easier to keep things moving smoothly—in fact, the amount of ice that can be harvested is proportionate to the number of rooms—small squads stationed in different rooms being able to take care of ice rapidly in a house of twelve rooms or more, as the workers can be changing skids in two or three rooms and filling in while the rest take the full supply of the elevator. Wide doors are also a help. The doors must be wide enough to admit a chute built so that the ice can run either way—i. e., wider in the clear than the diagonal of the cake. The doorman should be able to switch the ice any way and not have to direct it the narrow way. However, there are some disadvantages in wide doors, as they produce an increase in shrinkage of ice when the ice is being moved.

In laying out an ice house, where harvesting is done, care should be taken to properly grade the ground and place the building at sufficient distance from the source of supply to provide an easy incline and thus avoid the necessity of using knuckle wheels or any other unnecessary machinery, arranging it so that the doors do not face the water, and so that the house is not too deep, preferably with long, narrow rooms.

To prevent rise of temperature from the heat passing through the ground, it is desirable to have some of the storage space below the grade line, if possible about twelve inches below the frost line, governing the depth by drainage conditions.

If additional capacity is required, it is more desirable to build the house higher than to spread it out. Some consider a height of fifty feet better than to stop at thirty-four or thirty-five feet.

The filling of ice houses, where natural ice is harvested, is done by means of portable slides. These are placed on the ground, made up in sections, and lined with half oval iron strips to reduce friction. These lead to the foot of a gig elevator or lift which may be operated by various means, preferably motor driven. Where a storage house is built with more than one compartment, it may be equipped with one or more gigs and lowering machines, depending on conditions. Ice can also be delivered to the house, where the natural conditions do not suffice, by means of a platform at car floor height, 3′ 6″ above the rail. This platform is used, not only in storing ice, but also in case ice is desired to be shipped away.

One point which must be considered in an icing station is to avoid back travel of ice from one destination to another, or duplicate handling. Also, it is well to avoid the use of underground tunnels which mean expensive construction and maintenance.

An icing station of simple construction is usually a one-room storage with a gig elevator at one end which runs in a vertical direction through the ante-room annex to the storage room. The floor is usually 16′6″ above the top of the rail. Below the ante-room is an unloading platform 3′ 6″ above rail. This is not enclosed. Directly above the ante-room is the crusher room to which block ice is delivered. The gig may be reached at any one of the three elevations or at any elevation from the storage side. The opening to the storage side may be enclosed with hinged doors or boarded up and insulated as the house is filled, removing them as the ice is removed. The floor of the ante-room should be pitched, with a trough or gutter at one side. The flooring should be of 2″ matched material, made as water-tight as possible. Where a mechanical crusher is not installed, breaker bars of iron or wood are set in between the joists of the crusher room floor, using spouts for dropping ice to the cart below. The ante-room is used mainly as a storage space for block ice and carts for handling crushed ice, which facilitates the quick icing of a train. Platforms are usually 12′ wide x 200′ or more in length and

16′ 6″ high, running parallel to ice house and directly connected with anteroom of same.

These ice houses are usually of frame construction, the storage houses 32′ high with a gabled roof 1 x 6 D. & M. Bds., and asphalt shingles, and a straw or hay loft constructed between the collar beams and rafters of the roof construction. The straw or hay is thrown over the ice as the house is filled, for insulating purposes; and as the house is emptied, this material is reclaimed into the bin by means of a gig, buckets or forks.

A wall construction that has been successful in this type of house is constructed of 2 x 12 studs, placed 24-inch centers, covered on either side with 1 x 6 D. & M., diagonally, and over this a good, water-proof paper. On the interior, an additional layer of 1 x 6 is laid; on the exterior, drop siding. The space between the studs is filled with dry, hand-made, white pine shavings or similar material which will not pack. To prevent the passage of moisture to the insulation above, due to capillary action, it is preferable to fill the lower seven to ten feet of wall with granulated cork.

On the interior surface of the building it is desirable to use a good, water-proof paint, or spar varnish. The underside of the roof rafters should be ceiled up, leaving space at the ends of about two feet, forming a channel parallel with the rafters, allowing a circulating space for the warm air to ascend to ridge of the building. There should be an open monitor on the ridge of the roof. This need not be very high—just enough so that the rain will not beat in, and allow enough space for the warm air to pass out. One of the essential points in wall construction is that careful consideration be given to the sill plate that there be no air leaks. This can be effected by the use of offset joint well coated with car glue or other water-proofing material.

Due to the difference in temperature between the exterior and interior, walls exposed to the sun for a large portion of the day, especially south walls, are liable to warp. To overcome this, an additional air space formed of 2 x 6 studs and one layer of drop siding is built on the exterior face of the building after the storage wall is finished. There should be an open space left at the bottom and top for circulation, allowing hot air to pass out at the top.

Where a wall thickness of 16″ of insulation is desired, the construction, which has some merit of economy, is as follows: Studs are erected using 2 x 6 stuff, set opposite and 4″ apart, lacing the two by means of 2 x 4 girts 16″ long. This also makes filling easier, as fill will flow longitudinally.

At the lower portion of buildings which do not have concrete foundation, it is well to tie transversely with rods to avoid spreading; these should be below the floor to avoid obstruction. In the storage portion of an ice house, it is considered best to eliminate the use of interior supporting members, as there is objection to interior posts.

The floors of some refrigerated houses are constructed of cinders 12″ thick and in some cases over this a two-inch plank floor on sleepers has given good results. The floors should pitch slightly toward the center so that when the house is filled the ice forms an arch and does not throw any stress on the outside walls.

A 2″ plank floor on sleepers, on a 36″ cinder fill has been very effective and is a fairly cheap form of ice house floor.

In floor construction, water has to be contended with, due to poor drainage, and also where there is a great amount of shrinkage of ice on account of the heat transmitted from the ground. No definite construction will hold good in all locations.

Regarding platform construction: Some build doubledeck platforms; the lower one for handling cake ice to bunker and the upper for crushed ice from buggies to bunker, moved by means of portable spouts. Other railroads use platforms of one height, this being generally, 16′ 6″ above the rail, and, unless there is a great amount of crushed ice being handled, it has been found fairly advantageous. However, this requires a wider platform than where double deck is used.

There seems to be a difference in opinion as to the width of platforms. Some roads build platforms 12′ wide; these being constructed of wood posts, joists and 2″ plank floor, with guide strips for ice of oval iron let down flush with the floor, with slots between for dripping.

On the far side from the track, platforms have a guard railing, usually 3′ high with electric light poles with an overhanging arm. These poles are generally placed 32′ on centers. The arm projects out to the opposite side of the platform so as to get a maximum amount of light at the desired point at side of car. Some roads use island platforms between tracks. This has some advantage, as it allows two trains to be iced at one time.

Conditions often make it necessary to handle ice by power where it is necessary to save time, and for this purpose endless chain platform conveyors and inclines may be used.

The oval track heretofore referred to is only used in gravity operated plants and leads out from ante-room where house contains one, close to and parallel to the outer edge, on opposite side from icing track for entire length of platform. In this way ice can be handled to any point desired. However, this is not satisfactory where ice has to be handled around sharp curves, or for great distances by conveyors. In these cases, gravity slides should be of solid sheet steel, and sides of guides reinforced with iron at change of direction. In case of long conveyor, maple studding strips give best results.

Salt boxes are installed in connection with platforms. These are spaced about forty feet apart and hung below the floor boards of the platform. The salt is handled by means of a shovel from car to storage box. In some cases, elevators are used to carry salt, receiving supply from cars delivered to an overhead bin, using overhead trolley buckets or wheelbarrows to transfer to boxes under platform or other location.

Where crushed ice is handled, it is done by means of wheeled carts which are filled up in the house and stored there until a train is brought in alongside the platform. (Crushed ice carts are similar to a two-wheel truck, with handles like a wheelbarrow, of reinforced oak, and lined with galvanized iron, and are of sturdy, light construction, usually of 1,000 pounds capacity. Load should be balanced on axle.) They are then rolled out alongside the cars at the points where icing is to be done, and ice transferred by means of spouts or troughs into the bunkers. This requirement of an ice house affects the design, as, in some cases, where a great amount of crushed ice is to be handled, it is desired to use the double-deck platform. In many cases the crushers are placed above and discharge directly into carts in ante-room. Crushed ice is also handled by dumping it into cars from carts by use of a folding chute, mounted on a truck, traveling on a track about six feet below upper platform.

TYPICAL LAYOUT FOR ARTIFICIAL ICE

The arrangement of some of the largest Western and Southwestern plants is along the following lines:

First, the boiler house, next the engine and compressor room, then the tank room, next an ante-room and, finally, a storage of either one or two rooms, all of these being in a line parallel with the railroad track. The ice is dumped directly into the ante-room for the tank room, and about January 1st all excess ice is placed in storage. This allows the plant to run full capacity for about ten months in the year. By the time the heavy icing season starts, all storage is filled, so that not only can the entire tank capacity be used directly for icing, but any excess demand can be met by drawing from the storage. We might state that manufactured ice only is used at these plants and, further, because of the seeming unreliability of Northern winters, plants of this description will probably soon take the place of most of the natural icing stations in the States.

Storage rooms are filled by gig elevators, and in taking out the ice, two single cake automatic lowering machines, side by side, or incline conveyors, are used. The lowering machines are probably the best type which can be used, because of the simplicity of the repairs. In houses of large storage, flexible incline conveyors have been found very successful.

Steel runs are used to handle by gravity the ice in storage to and from the gigs and when lowering; because of the use of single cake gigs and safety bars, it has been found possible to do away with the man stationed at the machines.

The ante-room acts as a gathering place for sufficient ice to take care of the daily needs, icing trains, carload ice and a small amount of retail ice, also storage for unused ice left after icing a train.

The icing equipment has changed in character within the last few years, because of the fact that the railroads demand that the icing platforms be isolated from the building, which permits them to pull in a train on one side, uncouple, back in on the other side, and thus ice the full train at one time with no switching. These stations are usually located at a terminal point so that by the time a fresh engine is ready to pull out, the icing is done without delay.

To conform with this arrangement of platform, the ice is elevated up and over or down and under the near track, then lowered or raised, as the case may be, to the icing platform level 14′ 6″ or 16′ 6″ above the rail. We have found it best to go over the track. The type of machine to handle these conditions most satisfactorily seems to be the single double roller chain located centrally in the ante-room and extending the full length which allows loading from all points with very short hauls at a rate of about 10 to 12 cakes per minute. This chain runs in steel guides its entire length and as it approaches the track side of the building it is held in position as these guides curve up, continue at an angle, curve back to the horizontal and continue to a point central of the conveyor below, or by use of retarding device. The icing platform is usually 1,000 feet long, 15 feet wide, with chains located nearly central. The equipment consists of two single chain conveyors offset one from the other 6″, the driving machinery being located 500 feet distant from each end of the platform. One motor, two clutches with the necessary gears and driving shafts make up the drive which is so designed that for a distance of 10 or 12 feet the chains run side by side, which allows the transfer of ice from one to the other in either direction without labor, assuming, of course, that the conveyors have been synchronized when started. This arrangement allows either one or both chains to be operated as requirements demand. Both chains always run in the same direction and are reversible, this being necessary in order to redistribute the ice to points where there is a shortage.

Icing a train really starts about ½ to ¾ of an hour before it arrives, at which time the chains are started, delivering ice to all points on the platform where it is kicked off, until the platform is full. Only one ice slide is required to deliver ice to the far bunker of one car, the ice for the near bunker of the other car being pushed direct from the platform.

A carloading platform is usually installed between the near track and the plant, this platform being parallel to the track and approximately 600 feet long. A chain is used for transferring the ice from the ante-room to the cars, which are loaded and shipped to nearby points, either for retail business or for ice cars wherever there may be a shortage. However, it serves a second purpose, which is to receive carload ice from the cars and deliver it into the ante-room. This oftentimes happens when the icing business reaches unusual proportions; thus using up the entire amount in storage, leaving only the daily capacity of the tanks, which is insufficient.

Attached hereto is a description of three different types of icing problems and facilities designed to meet requirements at each point.

Icing Facilities—Gwin, Mississippi

The icing facilities at Gwin, Miss., are used for the icing of all cars handling perishable freight north and south bound shipments. Usually switch engines handle the cars to and from the platform, but the yard is so arranged that road engines can take the trains direct to and from the platform. The original plant was owned by outside parties and consisted of a refrigerating plant of 100 tons capacity, two storage rooms of 3,750 tons and 800 tons capacity, and an elevator with operating machinery located in the large storage room. The ice was delivered by incline conveyors, from the storage rooms to the elevated icing platform, which was 1,080 ft. long, and thence along the platform by conveyor to the cars. This plant was totally destroyed by fire in July, 1919.

In building the facilities described below on the same site, provision was only made for storage rooms and a train icing platform with a crusher to allow for handling crushed ice, in addition to the cake ice, as might be required.

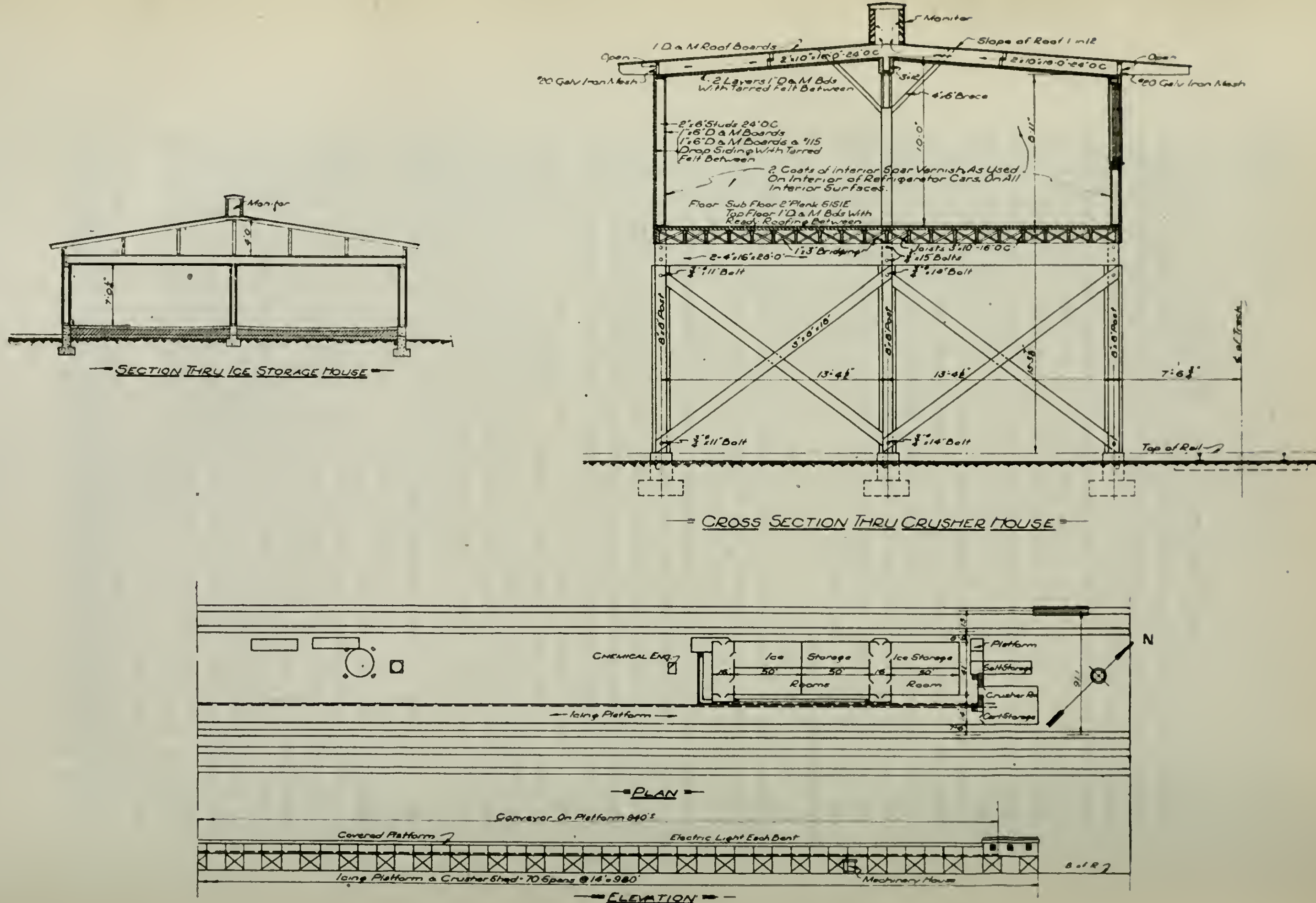
During the icing season, manufactured ice is brought daily in cars from plants at near-by towns and is handled direct to the elevated platform and into the cars, or to the house for storage, as the case demands. A sufficient amount of ice is retained in the house to provide for emergencies, or to carry over periods of light deliveries to the house.

The present facilities lie northeast and southwest and consist of an ice storage house, a salt storage house, and ice crusher house, an elevated train icing platform, a gravity incline, electrically operated conveyors, a track on the west side for delivering ice into the house, and a track on the east for icing trains.

The ice storage house has a capacity of 500 tons, it is 41 ft. wide and 181 ft. long, containing six storage rooms, each 41 ft. by 19 ft. with a 7 ft. 2 in. ceiling, and two anterooms 40 ft. by 19 ft. with an 8 ft. 11 in. ceiling height. The foundation and floor are of concrete and each storage room has a floor drain connecting with a gravel basin, and then to a sewer. The concrete floor is covered with removable sections of 2 in. by 8 in. cypress plank, spaced 1 in. apart, on 2 in. by 4 in. battens 24 in. apart.

The superstructure of the house is of wood construction, the exterior walls of the ice storage rooms being made up of 2 in. by 10 in. studding 24 in. apart, the outside faces of which are covered with 1 in. D & M sheeting, and then with one layer of tarred felt paper over which is placed the cypress siding for the finished wall. The interior side of the studding, also both sides of the partition studding and the ceiling joists of the storage room are ceiled with two thicknesses of 1 in. D & M sheeting. A layer of tarred felt paper is placed between the two layers of sheeting on the walls only.

The space between the studding of the exterior walls and partitions is filled with burnt granulated cork, while the space between the 2 in. by 12 in. ceiling joists is filled with shavings and covered with 1 in.



ICING FACILITIES—ILLINOIS CENTRAL RAILROAD—GWIN, MISS.

D & M sheeting. The exterior walls and interior partitions of the ante-rooms are made up of 2 in. by 6 in. studding, spaced 24 in. apart, and the ceiling joists are 2 in. by 6 in., spaced 24 in. apart.

The roof rafters are 2 in. by 6 in., spaced 24 in., and are supported by a continuous plate carried on 2 in. by 4 in. struts, 48 in. apart, which are fastened to the 2 in. by 12 in. ceiling joist over the storage room, and 6 in. by 10 in. girders over the ante-rooms, 1 in. D & M sheeting being used for roof boards, covered with ready roofing.

Along the ridge of the roof and extending the full length of the building is mounted a monitor 2 ft. wide and 2 ft. 3 in. high, with louvers on the sides, covered with No. 20 galvanized wire of ½ in. mesh. The space between the wall plate and the under side of the roof boards is left open, and covered with No. 20 galvanized ½ in. mesh wire, for ventilation, and to act as an insulator against sun action.

The entire interior wall surface was given two coats of interior Spar varnish. The windows have double sash, and all doors in the house are insulated cold storage doors.

The crusher house is located northeast of the ice storage house, and is supported on 8 in. by 8 in. posts on concrete footings. The floor joists are 3 in. by 10 in., 16 in. apart, with a sub-floor of 2 in. plank, a layer of ready roofing and then the finished floor of 1 in. D & M. The walls are 2 in. by 4 in. with sheeting and siding as in the ice house, but the layer of tarred felt paper and the cork filler between the wall studs were omitted in this case. The roof joists are 2 in. by 10 in., 24 in. apart, with monitor and similar construction as on the roof of the ice house. The carts are stored in the crusher house when not in use, and there is also space for the temporary storage of cake ice, if needed.

The salt storage house, located north of the ice storage house, and west of the crusher house, is a car body remodeled for the purpose, with platforms and steps connecting these three buildings, which have different floor levels.

The elevated train icing platform, located on the east side of the ice house and paralleling the icing tracks, is 14 ft. wide, 980 ft. long, and 13 ft. 3 in. above top of rail. It sets upon 8 in. by 8 in. posts, of 14 ft. centers, which in turn rest on concrete footings. The posts are cross braced with 3 in. by 8 in. plank. Two pieces of 4 in. by 16 in. notched into the posts, make up the girders, which carry 3 in. by 10 in. floor joists, 16 in. apart, with 2 in. plank flooring. The posts extend to the roof, which is 1 in. D & M boards and ready roofing. The west side of the platform is closed in with 1 in. by 12 in. boards and 1 in. by 2 in. battens, with windows hinged at the top, at every third bay of wall construction.

The ice house floor is 1 ft. 6 in. above the top of rail, and on the same level, at the ante-room doors each side of the house, are platforms for handling ice in and out of the house. Those on the west side are

Icing Facilities—Illinois Central Railroad—Gwin, Miss.

used in unloading blocks of ice from cars into the storage rooms, and the platforms on east side of house, next to the high platform, are used for moving the ice either into the storage rooms or from the house to the conveyor.

Electrically operated conveyors along east side of the building at first floor level, move the ice from the receiving gravity incline at south end of the house, to the ante-room doors, or to the incline elevating conveyor, at the crusher room. The operating machinery for this low level conveyor is in a house under the high platform, and that for the

Icing Facilities—Illinois Central Railroad—Gwin, Miss.

incline elevating conveyor is in the crusher house. On the elevated train icing platform is a conveyor 980 feet long, with the operating machinery located in a house at south end of the platform.

Manufactured ice is delivered in cars to either ante-room, on west side of the house, where the blocks are taken from the cars and stored in the house by hand. The cars can also be unloaded on the platform at the south end of the building and ice sent by a gravity incline to the low level conveyor, which delivers the ice either to the ante-rooms or the crusher room.

After the block ice arrives at the crusher house, it can either be crushed and delivered to the cars of a train in carts from the elevated train icing platform, or the cake ice can be delivered by conveyor on the high platform, alongside of a train to be iced, when the ice is taken from the conveyor by men and placed in the compartments of refrigerator cars. A deflector is located on the north side of the operating machinery house, to prevent cakes of ice from going into the machinery, if left on the conveyor, and this ice is stored temporarily on the platform and later returned by conveyor for storage in the house, or delivery to the cars. The ice runs and guides for the gavity inclines, and conveyors, are made of oak, and in some cases are metal covered.

The electric lighting system of the facilities is so arranged that the plant can be operated with the same efficiency at night as in the day time.

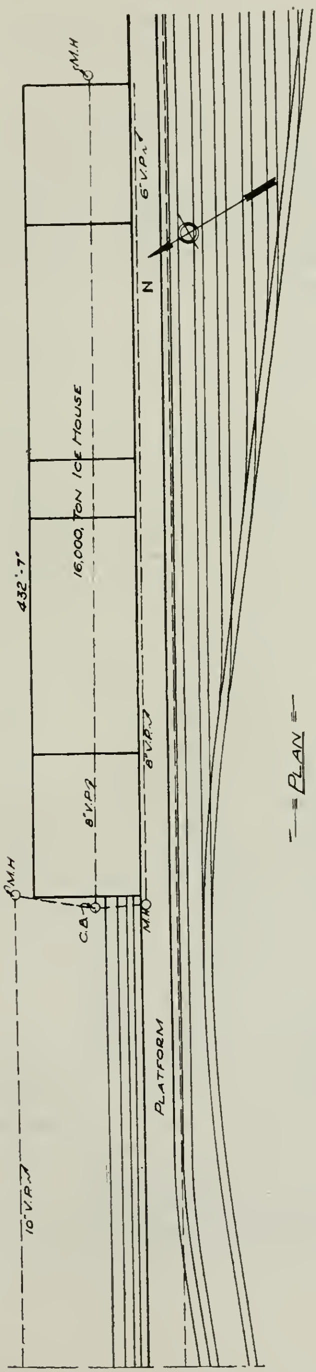
Icing Facilities—Waterloo, Iowa.

These icing facilities are used for eastbound shipments of meat and packing house products from South Omaha, and also for fruits and vegetables from California. While some westbound shipments require icing at this station, those eastbound are much greater.

Originally the icing of cars at this point was done at a platform about 600 ft. long, located at the side of an ice storage house of 1,500-ton capacity. The method of handling the ice at this old platform and ice house was crude and entirely inadequate to meet the demands on the plant, as the perishable shipments in both directions through this station increased. The cake ice was handled into and from the house, by means of block and tackle and delivered to cars standing at the platform on run-ways, the ice being moved along the run-ways by man power. If crushed ice was required, the blocks of ice were broken in a large wooden box or bin, by means of wooden mauls handled by laborers. To meet the demand for men to operate the plant at the time of icing a train of cars, it was necessary to call on trackmen or any other labor that was available.

To provide modern methods at this plant, and save a large part of the time required for cars standing at the platform, the house and platforms were rebuilt and enlarged, installing electrically operated mechanical conveyors, elevators and crushers, with provisions for handling both block and crushed ice. This facility, built in 1917, consisted of a 10,000 ton ice storage house, with salt storage bins, a crusher room, elevating and lowering machinery, electrically operated conveyors, gravity inclines, skids, a double deck train icing platform and tracks. The house was made 57 ft. 6 in. wide and 280 ft. 10 in. long with a ceiling height of 35 ft. Half way between the ends of the building is a working space, which is 29 ft. 6 in. by 57 ft. 6 in. and the full height of the building, dividing the building into two separate storage rooms. This working space has three floor levels to match the different icing platform levels at the side of the building, which parallel the icing tracks.

The foundation of the house, footings for posts, and the floors of the storage rooms are concrete. The superstructure is of cypress and



ICING FACILITIES—ILLINOIS CENTRAL RAILROAD—WATERLOO, IOWA yellow pine timbers construction. The removable sectional floor in the two storage rooms and the siding and all outside trim are cypress lumber. All other lumber is yellow pine.

The foundation walls of the house are concrete 15 in. thick and 8 ft. high. The exterior face of these walls is covered with Wesco Fiber-kots, an asphalt, asbestos fibre waterproofing paint, while the interior face of the wall is furred with 2 in. by 4 in. pieces, spaced 24 in. apart. These in turn are covered with two layers of 1 in. by 6 in. D & M sheathing, with one layer of tarred felt paper between them, the first layer of sheathing being laid diagonally. The space caused by the furring strips is filled with granulated cork.

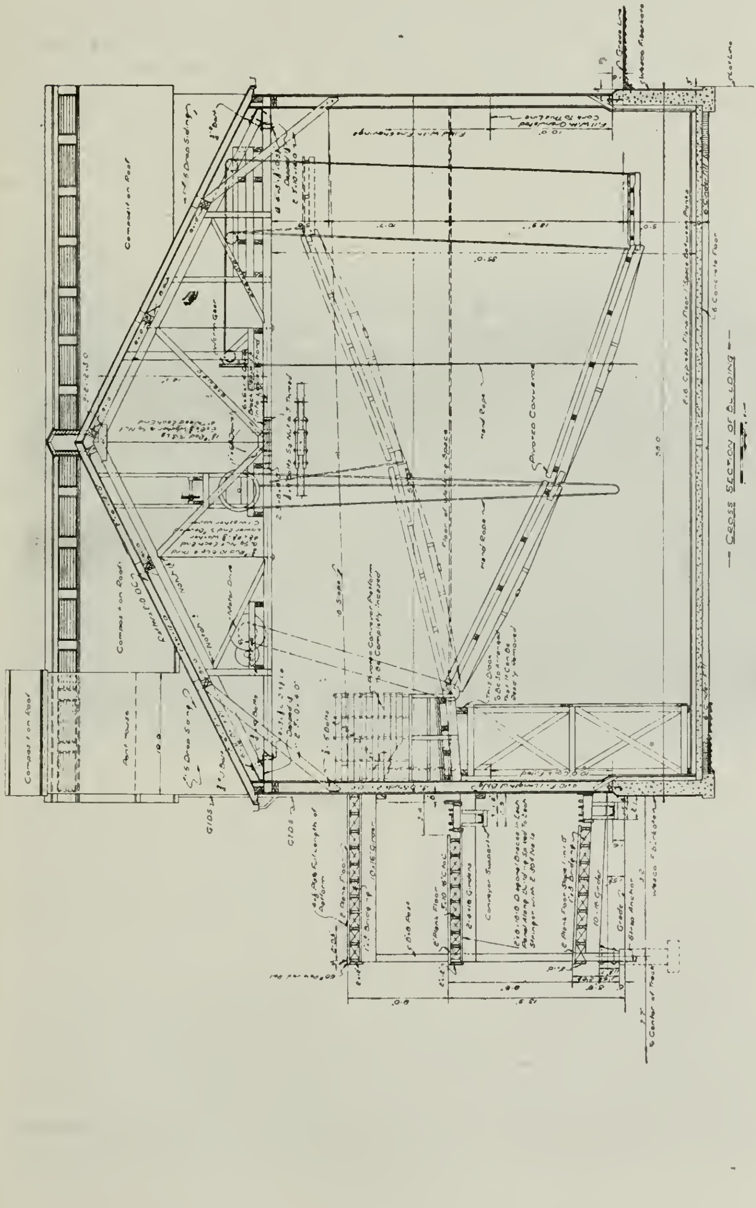
The concrete floor of the storage rooms, which is 5 ft. below the ground, slopes to a trough in the center of the room, running longitudinally and connecting with floor drains, which in turn connect with a gravel basin and then with the sewer. On the concrete floor is placed a super-floor of 2 in. by 6 in. cypress plank with a 1 in. space between, on 4 in. by 4 in. sleepers, spaced 24 in. apart.

The walls of the buildings are made up of 6 in. by 10 in. posts 18 ft. apart, supporting the roof trusses; and 3 in. by 10 in. studding, spaced 24 in. apart. The inner side of the studding is covered with two layers of 1 in. by 6 in. D & M sheathing with one thickness of tarred felt paper between, the first layer of 1 in. by 6 in. sheathing being placed diagonally. The outside face of the studding is covered with one thickness of 1 in. by 6 in. D & M sheathing, laid diagonally, and then with one thickness of tarred felt paper which is covered with siding for the finished wall. The space between the studding for a height of 10 ft. above the foundation wall is filled with burnt granulated cork, the remaining height to the roof being filled with fine wood shavings.

Framed wood trusses supported on 6 in. by 10 in. posts in the side walls carry the roof, which is made up of 8 in. by 10 in. purlines, and 2 in. by 6 in. joists spaced 24 in. The top and bottom sides of the roof joists are ceiled with 1 in. sheathing, the covering for the roof boards being prepared roofing. The space between the wall plate and the under side of the roof boards is left open and covered with No. 20 galvanized wire, ½ in. mesh, for ventilation and air insulation against sun action. On the center of the roof, extending the full length of the building, is a monitor 2 ft. wide and 3 ft. high, with louvers in each side covered with No. 20 galvanized iron wire of ½ in. mesh.

The first floor of the "working space" is of cinders, and is at the same elevation as the surounding ground. This floor is used in filling the house with ice received from the platform conveyor on the northwest or from motor trucks on the northeast, this ice being sent to elevating and lowering machines on the north or south side of the working space, by means of a set of gravity slides and switches.

The second floor of the "working space," which is 13 ft. 3 in. above the top of rail of the icing track, is made up of 2 in plank on 3 in. by 10 in. joists, 12 in. apart, which are carried on 10 in. girders, resting on oak



ICING FACILITIES—ILLINOIS CENTRAL RAILROAD—WATERLOO, IOWA corbel blocks set upon 8 in. by 8 in. posts. This floor was used in icing cars with cake ice and has a set of gravity slides from the elevating and lowering machines, which deliver ice to the platform conveyors.

The third floor of the "working space," which is 22 ft. 3 in. above the top of rail of the tracks, has a sub-floor of 1 in. plank laid diagonally, then one thickness of waterproof paper, and a finished floor of 2 in. plank. The floor slopes to a gutter along the west side of the room, which is connected to downspouts. This floor is used for the making and handling of crushed ice. The crusher is upon a platform 7 ft. above the floor on the center line of the elevating and lowering machinery in the

Icing Facilities—Illinois Central Railroad—Waterloo, Iowa

center of the room. This is arranged so that cake ice can be delivered to the crusher from either elevating and lowering machine on the north or south side of the working space. There are double sash windows at each end of this room, and the windows on the west side of the building are partly protected by sun shades. The roof over the working space runs east and west, and is carried on framed wood trusses of similar construction to that of the main building.

Along the west side of the ice house, paralleling the icing tracks are three levels of platforms, 13 ft. 9 in. wide, and extending the full length of the building, and beyond at each end, with a total length of 1,009 ft. The first platform level is 3 ft. 9 in. above grade, and the floor slopes towards the conveyor, which is located along the platform close to the building. The second floor is 13 ft. 3 in. above grade, the same elevation as the second floor of the working space, and is built level with the conveyor along the platform close to the building. The third floor of the platform is 22 ft. 3 in. above grade, corresponding to the third floor of the working space, and has a sloping frame canopy of composition roofing with a frame hood to give additional protection from the weather.

The construction of these platforms is of yellow pine lumber. The 8 in. by 8 in. posts extend from the concrete footing to the third platform level. The other pieces used are 10 in. by 16 in. girders, 3 in. by 10 in. joists spaced 16 in. apart, and 2 in. plank for floor.

In operating the plant as first rebuilt in 1917, the natural ice from the surrounding country was received at the first floor platform in cars and

Icing Facilities—Illinois Central Railroad—Waterloo, Iowa

delivered by the conveyors to the working space; also ice was delivered by wagon direct to the working space, where the blocks were handled by the elevating machines, into the storage rooms. In taking blocks of ice from the storage rooms for icing of cars, the method of handling was the same, the successive steps being simply reversed. But as the operation of the plant progressed, it was found that the facilities for handling ice into the house were entirely inadequate. This was especially true if the winter's supply of natural ice was small, and it became necessary to bring manufactured ice to the platform for storage in the house. At such times there might be cars of ice for storage held out by train of cars being iced at platform. In these cases, the icing of cars at the platform was done from cars on an adjoining track, the ice being handled from car to car by hand.

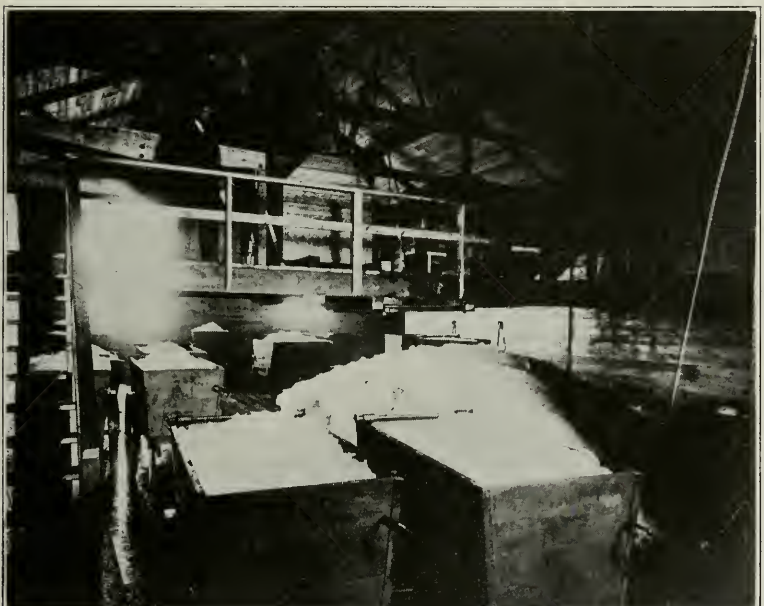
As the perishable shipments through this station increased, which were especially heavy during the period of the World War, making larger demands for ice, it was found that the storage space must be increased and in 1918-1919 an additional storage capacity of 6,000 tons was added to the house, and later, in 1919, to facilitate the handling of the block ice into the house, there was made midway between the two ends of each storage room at the second floor platform, doors through which cakes of ice are handled for storage. Inside the building, at each

Icing Facilities—Illinois Central Railroad—Waterloo, Iowa

of these doors, is a platform and a flexible conveyor 44 ft. 9 in. in length, one end of which is fastened to the platform at the floor level, while the other end can be raised or lowered by means of cables and pulleys hung from the roof trusses to meet the levels of ice as stored in the house. These flexible conveyors proved so very successful in handling ice into the house that they are now used also for moving block ice out of the storage rooms to the platform conveyors, and the elevating and lowering machines are now used exclusively for moving cake ice from the storage rooms to the crusher room above.

To provide better facilities for the unloading of cars of ice at this house, there was built, in 1919, an elevated trestle of pile and timber construction, 10 ft. high at the north end of the house, on the east side of the platform, which brings the floor of the car on the same level as the second story platform. The trestle has a capacity of seven cars, and ice from these is placed on the platform conveyor which delivers to the house for storage, or direct to the cars where the ice is placed in the bunkers.

The block ice for cars is taken from the storage rooms at second platform level, being received from the flexible conveyors in the house, and placed on the platform conveyor, which delivers it to the cars, where



Icing Facilities—Illinois Central Railroad—Waterloo, Iowa

it is placed in the bunkers by hand. When the ice is to be taken from the house for crushing, the cakes are moved from the storage rooms by means of the skids to the elevating machines in each storage room, at the wall of the working space. The elevating machine is so arranged that a receiving basket is installed to receive the cake of ice from the skids. From this basket the ice is taken by the machine and delivered to the crusher on the third floor of the working space, and after passing through this machine which breaks it into pieces less than 1 ft. cube, it is delivered to the cars in carts traveling along the third floor platform. From this platform the crushed ice is placed in cars by means of a No. 14 gauge sheet iron spout, hung from a 60-lb. iron rail placed along the edge of the platform for its entire length. The pipe section of this spout is 12 in. in diameter and the receiving end into which crushed ice is dumped from the carts increases to a 3 ft. by 3 ft. opening. The receiving end of the spout is fastened by a hinged arrangement to a two-wheel truck traveling on the 60-lb. rail, the wheels of the truck being 5 ft. apart. A third wheel 3 ft. from the truck and fastened to the end of a steel plate, prevents tipping. This third wheel travels along the platform on a ⅛ in. by 4 in. steel plate the full length of the platform. By means of a bent metal arm with movable counter-

Icing Facilities—Illinois Central Railroad—Waterloo, Iowa

weight, the discharge or lower end of the spout is moved through the arc of a circle to position, for the icing of cars. This operation and the moving of the truck with the spout along the platform is all done by hand from the platform level.

The salt used in connection with the icing of cars is delivered in cars and spouted to a concrete conveyor pit located under the first floor platform and directly under the working space. A conveyor takes the salt to a bin of 24-ton capacity in the crusher room on the third floor. This bin is 6 ft. 8 in. above the floor; it is of timber construction and is lined inside with 2 in. sheathing. The bottom slopes to the center where a spout with control gate allows the filling of carts. There is also an overflow spout at the top of this bin, discharging into a reserve bin of 24 tons capacity on the first floor. This bin is of frame construction, on a concrete foundation. The reserve bin is connected with the concrete conveyor pit, so that when the bin on the third floor is empty, salt may be taken from the reserve bin for the refilling of the higher bin. The salt is taken from the bottom of the bin on the third platform in carts, and carried to salt boxes of 600 lbs. capacity, located on every third post of the platform, just under the floor of this platform. These boxes are filled from the third floor platform and the salt for cars is taken from the bottom of the boxes by workers on the second floor platform.

Of the platform conveyors, there are two on the first floor platform, extending from each end of the long platform to the working space, with the operating machinery for each located in small frame houses, built on the platform, one each side of the working space. On the second floor platform, there are two conveyors extending from the ends of the platform to the working space, with the operating machinery in frame houses located at each end of the long platform. The third floor platform has no conveyor; the crushed ice and salt on this platform are handled in the carts propelled by man-power. These conveyors are operated by electric motors and can all be run in the same direction, so that it is possible to carry cake ice from one end of the platform to the other. Between the two conveyors at the working space, is a connection platform with ice runs, over which the cake ice is handled by men when traveling from one conveyor to the other.

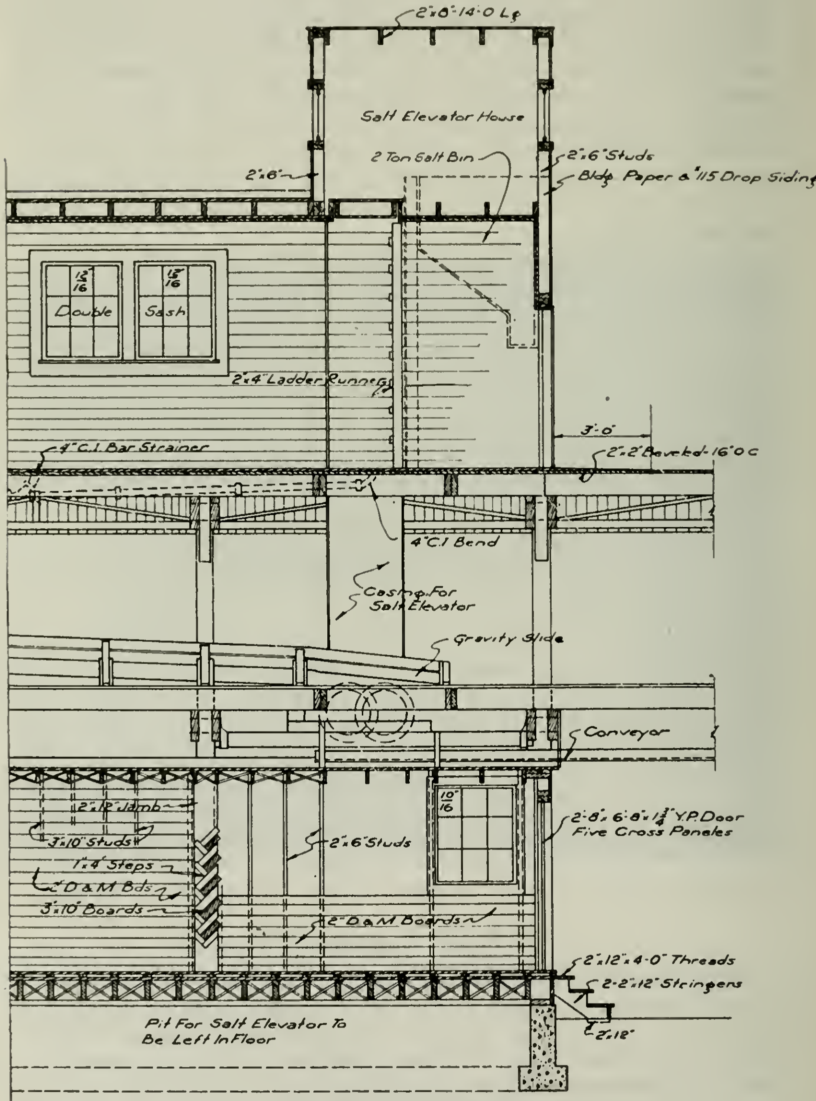
The ice runs and guides for the gravity inclines and conveyors are of maple and in some cases are metal covered. A deflector is located on the south side of the north operating machinery house, and another on the north side of the south machinery house to keep cakes of ice from going into the machinery if they are left on the conveyor. This ice is stored on the platform temporarily, the conveyor is reversed and the blocks are returned either to the house for storage or placed in the car bunkers.

The electric lighting system in the facilities is so installed that the plant can be operated with the same efficiency at night, as in the day.

Icing Facilities—Jackson, Miss.

The icing facilities at Jackson, Miss., are used chiefly for icing northbound shipments of fruit and vegetables. As this business increased at this point, it was found necessary to provide more adequate platform space and conveyors than were there originally. Also it was thought advisable to provide better track arrangements and save the time required to switch the cars to and from the old platform.

The manufacturing plant furnishing ice at this station is located to the west of the right-of-way, and the old platform with a stub track each side was located on the wayland close to the property line. This required



HALF SECTION THRU CRUSHER HOUSE

ICING FACILITIES—ILLINOIS CENTRAL RAILROAD—JACKSON, MISS.

a switch engine to handle cars to and from the platform. By the new plan, the train icing platform was made about twice as long as the old, and the location moved to the east, providing train icing tracks on each side of the platform, connected at each end with main tracks, which make it possible to handle the trains direct to the icing platform with the road engines.

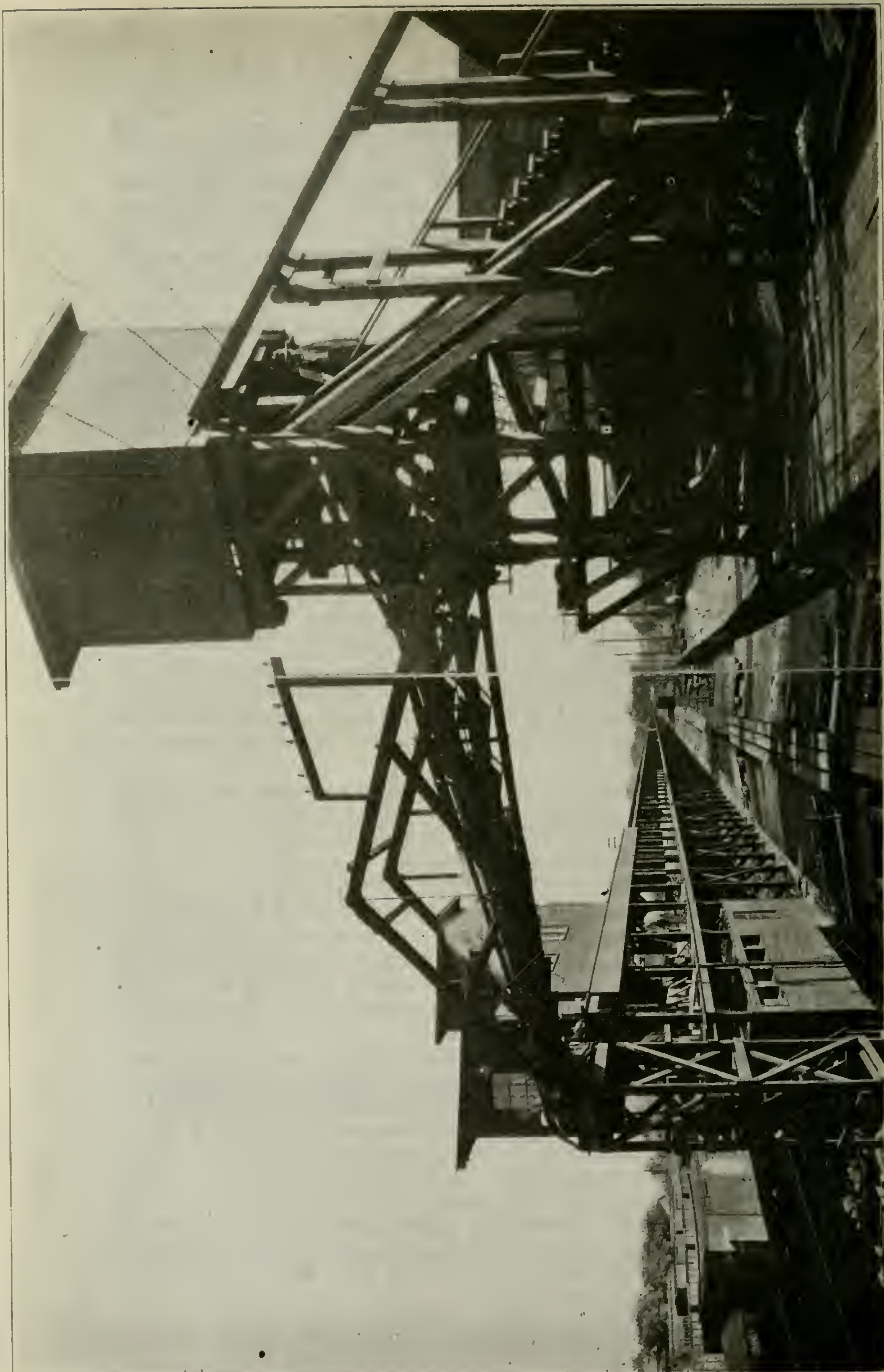
The facilities lie north and south and consist of a cross-bar double chain, inclined elevating conveyor, a gravity ice slide across the tracks supported upon a double Howe truss bridge, an elevated ice crusher house, salt storage and handling facilities, a high icing platform, part of which is double decked and having car icing tracks on each side, and platform ice conveyors. This installation, which handles 8,260 tons of ice per year, does not have an ice storage house, as the ice is brought direct from the plant of the manufacturer to the platform, by the conveyors, as needed.

The cake icing platform, which is 13 ft. 3 in. above the rail, 12 ft. wide and 1,652 ft. long, with icing tracks on each side, is of yellow pine lumber construction. The platform, also the roof over it, are supported on 8 in. by 8 in. posts on concrete footings. These posts are spaced 14 ft. apart, and are braced both ways below the platform, with 3 in. by 3 in. plank. The 2-in. plank floor is supported on 3 in. by 10 in. joists, spaced 16 in. apart, which in turn are carried on girders of two pieces of 4 in. by 16 in. timbers, set into the side of the posts. The roof over the platform is ready roofing on 1-in. D & M sheeting, which is supported by 2 in. by 6 in. joists, 20 in. apart, on 2 in. by 10 in. girders, set into the outside face of the posts.

A conveyor located on its center line and extending practically the entire length of the platform, allows cars on either side to be iced. This conveyor is divided into two equal parts with operating motors and machinery located midway between the ends of the platform. It is reversible, so the ice may be conveyed continuously in either direction.

At the north end and under the platform is a salt storage house on a concrete foundation, 42 ft. long and the same width as the platform. This house contains a storage bin 28 ft. by 11 ft. 6 in. and a working space 14 ft. by 11 ft. 6 in. The salt bin has a capacity of 50 tons, and is filled by hand from cars at the side of the bin, through wooden doors hinged at the top.

The salt house is made of 3 in. by 10 in. studs, spaced 16 in. apart and lined inside with 2 in. D & M plank. The outside is covered with drop siding. The floor is made up of 2 in. D & M plank laid on 10 in. by 4 in. strips spaced 16 in. apart, over a subfloor of 2 in. D & M plank on a 3 in. by 10 in. floor, with the joists spaced 16 in. apart. The ceiling joists are 2 in. by 6 in., spaced 16 in. apart; over them are laid 1 in. D & M roof boards, covered with ready roofing. The salt is shoveled by hand from the storage bin into an elevator hopper, in one corner of the working space. The elevator, which is an electric driven chain bucket type, elevates the salt to a two-ton bin above the crusher house floor level, or about 28 ft. above the top of rail.



The ice crusher room is 11 ft. 6 in. wide and 42 ft. long with a 9-ft. ceiling at the low point. The construction of this room is the same as of the icing platform as to joists and girders, but the floor is made up of two layers of 2 in. D & M plank with one layer of ready roofing paper between. The floor pitches to the west, on which side are three floor drains connected to a drain pipe which discharges the water upon the ground below.

The walls of this room are made of 2 in. by 6 in. studs, spaced 24 in. apart with 1-in. D & M sheeting on each side, the outside of the wall

Icing Facilities—Illinois Central Railroad—Jackson, Miss.

being finished with siding with one layer of tarred felt between the sheeting and the siding. The space between the wall studding is filled with burnt granulated cork from the floor to the ceiling. All of the windows have double sash and the doors are insulated cold storage doors, and were manufactured by the Stevenson Cold Storage Door Company. The ceiling is made up of two layers of 1-in. D & M boards with one layer of tarred felt between, which are nailed direct to the roof joists. The roof joists are 2 in. by 8 in., spaced 20 in. apart, and are supported by a continuous plate which is carried on the wall studding. The roof boards are 1 in. D & M and are covered by ready roofing. The roof slopes to the west and has a 3-ft. overhang on the sides.

The space between the wall plate and the under side of the roof boards is left open and is covered with No. 20 galvanized wire with ½-in. mesh. This is for ventilation purposes and air insulation against sun action.

Extending above the roof at the south end of the ice crusher room there is a penthouse 11 ft. 6 in. wide and 10 ft. long, with a 7-ft. ceiling, which contains the machinery for the salt elevator. In the southeast

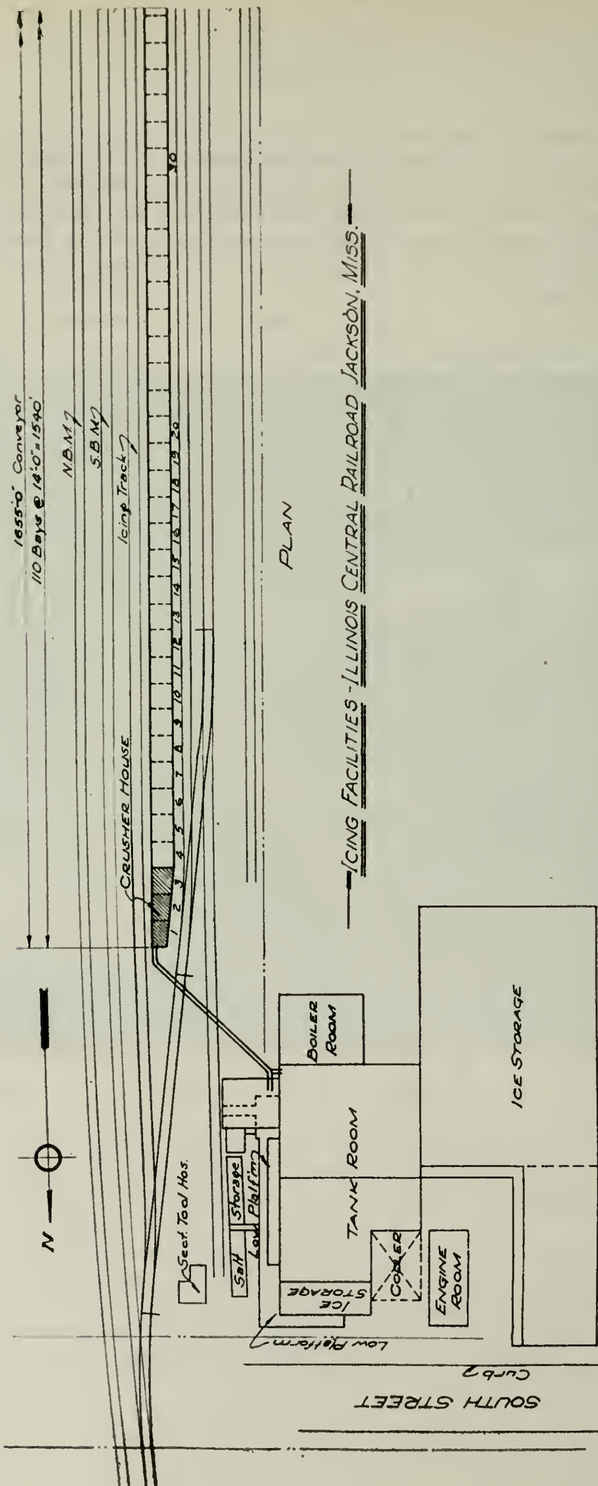
Icing Facilities—Illinois Central Railroad—Jackson, Miss.

corner of the crushing room, under this penthouse, is an elevated salt storage bin of two-ton capacity. At the bottom of this bin, and five feet above the upper platform level, there is a spout with control gate for filling push carts with salt.

To the south of the crusher room is a platform 84 ft. long and 21 ft. 3 in. above top of rail, approximately the same elevation as the low point of the crusher room floor. This platform, which is of the same construction and width as the cake-icing platform below, is used for icing cars with crushed ice, carts being the means of handling same. Just under this platform and fastened to the 8 in. by 8 in. posts are six boxes of 600-lb. capacity each, with a spout and gate control. Three of these salt boxes are located on each side of the platform, and they are spaced 28 ft. apart; salt is taken from them as the cars are being filled with crushed ice. The filling of these boxes is done from the crushed ice platform above, the salt being brought from the storage bin in the crushed ice room in carts.

Ice is delivered to a platform adjoining the manufacturing plant by means of conveyors owned and operated by the ice company. The ice is then elevated by means of an endless chain cross-bar conveyor, elevating at an angle of about 48 degrees. The ice then moves by gravity across the tracks on slides, supported on trusses, and passes into the crusher house. By means of a trap door, the ice is then either diverted into the crusher house for crushing, or on to a retarding gravity slide connecting with the chain conveyor on the cake ice platform below.

The machinery for operating the inclined elevating conveyor is located in a housing at the top of the conveyor. The trusses across the tracks, and 5 ft. apart, span 44 ft. and are clear 24 ft. above top of rail. These trusses also support a footway connecting the crusher house and ice manufacturing plant. The gravity slides where curved or exposed to severe abrasion are metal lined. The ice runs on the platform are made of oak. The conveyors and elevator are electrically operated. The plant is lighted by electricity and can be operated with the same efficiency at night as in the day.



Icing Facilities—Illinois Central Railroad—Jackson, Miss.

Appendix C

FLOORS FOR RAILWAY BUILDINGS

A. Crable, *Chairman;*
D. R. Collin,
W. L. Darden,
G. A. Mitchell,
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G. A. Rodman,
Sub-Committee.

The Sub-Committee to which this subject was assigned submits a report to cover the results of its preliminary investigations. This report is somewhat elementary in character and is intended to serve as a basis for more advanced research, which it is hoped the Sub-Committee will have opportunity to follow out next year. In the continued study of this subject it is desired to develop dependable information on the wearing qualities of the various types of floors, under actual working conditions, and to study specific cases of failure in an effort to determine if such failure was caused by inherent defects in the floor structure, by defective workmanship or by the selection of the wrong type of floor for a given installation.

Floors for Railway Buildings

The floor of any building, in which work is performed, is subjected to service much more severe than any other part of the building and may be considered as a part of the working equipment as well as a part of the structure. Therefore, any treatment of the subject of floors, as applied to railway buildings, logically follows a consideration of the different kinds of buildings in which floors of different types can be used most successfully.

In the following paragraphs an attempt is made, based upon what appears to be accepted practice, to indicate the types of floors commonly used in various railway buildings.

Freight Houses.

Probably the most common type of floor in use is the two-inch plank floor, laid on wooden joists or stringers. This floor is satisfactory and economical, except in locations of considerably more than minor importance, and is suitable for all frame buildings supported on posts or piers. In many cases, where wooden floors have become worn, the wearing surface in front of doors and on runways is renewed with not less than ⅞-in. dressed maple, square edged and end matched, laid on top of the original floor. Results show maple flooring so used to have a life of twenty years or more, even under heavy service, but on account of the expense involved its use is generally limited to that part of a floor which is subjected to heavy trucking.

In larger and more important freight houses, at terminals, and where a large amount of trucking is done, a floor of greater first cost is justified and in such locations concrete appears to give satisfactory results. Such a floor is fairly permanent, sanitary, easy to keep clean, and the type of construction used fits in well with the building foundation. Its disadvantages are failure of the wearing surface, especially at expansion joints, and an unyielding surface which occasionally produces complaints from truckers. Expansion joints should be as few as possible and located outside of the heavily used surface wherever practical.

In locations where concrete floors are for any reason not considered satisfactory, some different type of wearing surface, such as wood or asphalt blocks or asphalt mastic, may be laid on a concrete foundation. This type of construction adds materially to the first cost.

Transfer Platforms.

If of wooden construction, floors on transfer platforms should be laid with the planking parallel to the line of trucking traffic, unless iron plates are used for a trucking runway, when they may be laid at right angles if the construction of the sub-structure requires. However, when plates are used repairs can be made much more easily if planks are laid longitudinally.

Where trucking traffic is not too heavy concrete floors are in some cases used, and for extremely heavy traffic a concrete base with wood or asphalt block or mastic wearing surface is used.

Freight Storage Houses.

For freight storage houses, which are usually of fireproof construction, concrete floors are generally approved.

Freight Piers.

Floors on freight piers must of necessity largely conform to the style of construction used in the pier. They should be fire-resisting and in many cases must have flexibility enough to take up the vibration caused by boats being moved along the pier.

Engine Houses.

For minor houses, where not many running repairs are made, especially houses of frame construction, a floor of clean engine cinders, well compacted, is sufficient to meet all requirements.

For houses of more importance concrete or brick give excellent results.

For houses of a still higher grade, a floor of brick or creosoted wood block on a concrete base is recommended.

Asphalt floors, either mastic or block, are not recommended for engine houses since the action of steam and oil is likely to cause their failure.

Blacksmith Shops.

Cinder floors are preferred in all cases.

Machine Shops.

In small frame buildings a wood plank floor, of thickness to correspond with severity of service it has to withstand, is commonly accepted as good practice.

For buildings of a higher grade, wood block floors, preferably of treated material, give excellent results. Asphalt blocks or mastic produce an excellent floor, but in some cases have not been found entirely satisfactory because of the detrimental effect of oil drippings around machines, and in locomotive shops.

Concrete floors have in some cases been found to be undesirable because they lack the resiliency and dryness necessary for the comfort and health of men employed constantly in shop buildings, and tools or finished machine parts are frequently damaged by falling on them. Where concrete floors are used it is found that workmen frequently provide themselves with wooden platforms to work upon. These are objectionable as dirt collectors, they get oil soaked and produce a fire hazard.

Concrete floors have been found to be satisfactory in erecting shops.

Paint Shops.

In passenger car paint shops a concrete floor seems to meet all requirements satisfactorily and it is doubtful if circumstances would justify the use of a more expensive type of floor. In freight car shops, where paint is sprayed on, a floor of cinders is suitable.

The use of concrete floors in paint shops or any other shop where tracks run into the building makes it necessary to provide a permanent type of track construction so as to avoid frequent damage to the floors when making track repairs.

Freight Car Repair Shops.

Wood floors can be used if something better than cinders is desired and if provision has to be made for trucking material between tracks, but if material is handled by overhead cranes cinders will produce a very satisfactory floor.

Store Houses.

Concrete floors are satisfactory and are in common use, but for locations where very heavy material is handled wood block is to be preferred.

In small store houses, at outlying points, the ordinary wood plank floor meets all requirements.

Oil Houses.

Because of the necessity for fireproof construction concrete is the only flooring suitable for oil houses.

Carpenter Shops.

In carpenter shops where considerable bench work is done wood plank floors are desirable because of the comfort to workmen which they afford.

Concrete floors in such buildings are easily kept clean and for this reason are sometimes used.

Office Buildings.

Office buildings of the better class should have oak, maple or dense pine floors as indicated by the use for which the various rooms are intended. For hallways and toilets terrazzo, mosaic, tile or some kind of a sanitary composition floor is to be preferred, provided the importance of the building warrants the expenditure.

For office buildings of lesser importance floors will naturally be of composition, concrete or pine. If concrete is used it is desirable to cover it with linoleum or cocoa matting for added comfort to employees. Passageways between desks may be covered with rubber runners.

Passenger Stations.

In large city stations and in suburban stations of importance, terrazzo, mosaic, tile or some high grade type of composition floor is generally accepted as best meeting the requirements. In such locations the architectural suitability of the floor is of as much importance as its wearing qualities. For ramps, a non-slip wearing surface is essential.

For second grade stations and for small stations at outlying points, concrete or wood floors are commonly used and give entire satisfaction.

In stations where concrete or terrazzo floors are used a wood floor should be provided in the ticket office.

Signal Towers.

Floors in signal towers are to a certain extent dependent upon the style of construction of the building and may be of concrete, composition or wood.

Concrete floors are not desirable where there is electrical machinery unless a dense, hard, permanent surface can be obtained to prevent dusting.

Appendix D

FREIGHT HOUSE DESIGN

A STUDY OF THE PRINCIPAL FACTORS WHICH GOVERN THE DESIGN OF THE LEVEL L.C.L. FREIGHT HOUSES

Hugo Filippi, *Sub-Committee.*

Introduction.

While generally recognized the importance of adequate and correctly designed terminal facilities as a measure of economical operation has only in recent years been given the careful consideration which the question deserves.

In the past, the problem of L.C.L freight house design has been largely attended by a series of approximations and by comparison with existing freight houses through which substantially the same tonnage was being handled. Only too frequently the size of the house has been determined arbitrarily and the lack of careful planning has made itself manifest immediately upon completion of the structure.

L.C.L. freight facilities, particularly in large cities, are rapidly assuming an important position from a property investment standpoint. It is, therefore, of prime importance that this problem be given the closest possible study, to the end that the freight houses of the future may be properly and economically designed, not only in so far as such design affects the actual physical operation of receiving or stowing the freight, but also that the entire plant may be the result of a preconceived plan which will allow for expansion due to reasonable growth in business and one in which each factor has been carefully considered and given proper weight.

It should be recognized at the outset that the problem of freight house design involves more than a simple consideration of those individual factors which are related to the house design alone. A satisfactory solution must necessarily include a critical study of existing freight conditions and a broad vision as to probable future developments.

General Considerations.

L.C.L. freight consists of several distinct classes, each of which must be received in a particular manner and handled without delay.

In the larger terminal these classes are generally as follows:

INBOUND—RECEIVED
From Line

INBOUND—FORWARDED

City Delivery by Vehicle	To Connecting Lines by Vehicle	To Connecting Lines by Car	To Industries Within Terminal District by Car	To Own Lines Via Outbound House by Vehicle or Car

OUTBOUND—RECEIVED

From City by Vehicle	From Connecting Lines by Vehicle	From Connecting Lines by Car	From Industries Within Terminal District by Car	From Line Direct by Car	From Inbound House by Vehicle or Car

OUTBOUND—FORWARDED

L.C.L. Cars to Division Points on Line from which freight is distributed to local points by local freight trains	Solid L.C.L. Cars to Heavy Local Points	L.C.L. cars to Points on Foreign Lines via Own Line and Connections

Inbound House Operation.

L.C.L. inbound freight is received at the house in cars, unloaded, checked and placed on the floor of the house. Freight for city delivery is held on the floor until called for by consignee, while freight for industries and for connecting lines (and in some instances for the outbound house) is loaded into transfer cars or vehicles for delivery to proper destination.

Outbound House Operation.

Freight delivered to the outbound house by vehicle is received at the doors, checked, weighed, routed and loaded on house trucks for movement into proper cars in the outbound setting. Car transfer freight (freight from industries and connecting lines) is received either on house tracks or at a separate transfer platform adjacent to the outbound house setting.

After the freight has been received, movement into the proper car is accomplished either by use of hand trucks or, in the case of long houses, by placing on 4-wheel trucks made up into trains and handled by motors directly into or opposite the proper car where it is to be stowed.

Character of Business Handled.

A careful study of the general manner in which L.C.L. freight is received and forwarded draws attention to the necessity of determining the volume of each class of freight to be handled. While all the classes indicated above will not be found applicable to smaller freight houses, it is evident that in the design of large terminals all of these must be considered. The relation in tons of each class of freight to the total tonnage handled is, therefore, an important consideration.

A study of the business handled at a large freight terminal in Chicago developed the following approximate relations:

INBOUND HOUSE

Door Freight—City delivery, plus delivery to connecting lines by vehicle	70%
Car Transfer Freight—Delivery to industries and connecting lines	25%
Freight delivered by other means	5%
Total	100%

OUTBOUND HOUSE

Door Freight—City receipt, plus delivery from connecting lines by vehicle	40%
Car Transfer Freight—Received from connecting lines and industries	50%
Freight received by other means	10%
Total	100%

The above example is given merely as an illustration of the manner in which the data preliminary to design should be prepared and the percentages indicated should be understood as applying to this freight terminal only.

Growth of Business.

The next step lies in a determination of the probable future growth of business to be provided for in the design of the facilities. This problem is exceedingly complex owing to the number of variable factors involved, such as changes in industrial conditions, possible unification of terminals, changes in routing, pooling of shipments to make carloads, possible development of waterways, etc., but a careful study of past growth will do much to reveal the probable future tendency.

Mr. E. H. Lee, Vice-President of the Association, states in his excellent paper, "Notes on L.C.L. Freight Houses," Volume 15, page 364, that "the L.C.L. business is at present growing at the rate of about 5 per cent a year. It, therefore, doubles every fifteen (15) years." While this statement is quite general, it has been found to reflect the average conditions throughout the country. Whether the future growth will continue at this rate is highly problematical and it seems probable that the rate must decrease as the development of the country becomes more complete. The application of such a high rate of increase to the business growth at the average freight house results in such generous provision in capacity that its use for design purposes, however, must be questioned.

This thought leads to the advisability of providing house capacity capable of handling the ultimate freight business as determined by the physical life of the facilities. On general premises such a step appears illogical and careful study would seem to indicate the wisdom of providing facilities sufficient to serve present requirements plus a reasonable increase. Preconceived provisions in the general design of house and tracks should be of such character that an increase in facilities may be had at any time without destroying their unity.

Factors of Design.

After the relation between the various classes of freight has been determined and the volume of business for present and ultimate development has been decided upon, the problem resolves itself into a determination of individual factors of design, and it is these factors which will be discussed in the succeeding paragraphs.

Inasmuch as this study contemplates a discussion of these factors for one level L.C.L. freight houses only, no consideration will be given those which have a relation to multiple level houses. It is to be hoped that subsequent reports of the Association will consider the latter factors very fully and present data on that phase of the problem.

The factors which will be considered here are enumerated below:

- Width of roadway.
- Width of occupancy per vehicle against tailboard.
- Speed of vehicles along roadway.
- Average loading per vehicle in tons.
- Average loading per car in tons.
- Average time of loading or unloading per vehicle.
- Rate of turnover of freight received at Inbound House and relation to floor space required.
- Floor area required per ton of Inbound freight.
- Floor area required per ton of Outbound freight.
- Floor area required for storage of Outbound freight.
- Peak vehicle loads—Inbound and Outbound House.
- Average tonnage which can be handled per day per lineal foot of tailboard and per door.
- Tailboard required per car.
- Number and spacing of scales.
- Spacing of doors.
- Economic length of house.
- Floor live load, per square foot.

Width of Roadway.

The question of roadway width is dependent primarily on size of vehicles to be accommodated and whether the roadway will serve buildings on one or both sides. In order to obtain information on the size of vehicles commonly used for freight purposes, observations were made recently at the South Water Street facilities of the Illinois Central Railroad at Chicago. This information is shown in Table No. 1.

TABLE 1—SIZE OF VEHICLES

Data Obtained From Observations Made at the I. C. R. R. South Water Street Freight Terminal, Chicago, Sept. 14-15, 1921.

Location	Type of Vehicle	Name of Manufacturer	Extreme Width	Extreme Length	Height to Wagon Bed
Inbound Ho	Motor Truck	Oneida	7.50	24.00	3.50
" "	" "		5.42	17.25	3.50
" "	" "	Walker Electric	7.00	16.58	3.87
" "	" "	Diamond T	6.75	22.00	3.67
" "	" "	Indiana	6.00	18.58	3.25
" "	" "	Ford	5.42 H	15.50	2.50
" "	" "	Vim	5.50	14.00	3.58
" "	" "	Reo	5.50	16.83	3.00
" "	" "	Walker Electric	6.00	17.00	4.17
" "	" "	Old Reliable	6.00	18.50	3.50
" "	" "	Day—Elder	5.33	19.83	3.00
" "	" "	Autocar	6.17	15.83	3.33
" "	" "	Available	7.33	22.50	4.00
" "	" "	Atterbury	7.00	23.17	3.67
" "	" "	Ford	6.30	17.60	3.50
" "	" "	Federal	6.30	21.50	3.40
" "	" "	Ford (Trailer)	5.30	26.00	3.60
" "	" "	Sterling	6.70	24.00	3.40
" "	" "	Federal (Trailer)	6.60	25.00	3.60
" "	" "	Diamond T	7.40	22.50	3.70
Outbound "	" "	International	6.40	21.00	4.00
" "	" "	Sandow	7.60	24.90	3.60
" "	" "	Pierce Arrow	7.40	21.60	4.00
" "	" "	Packard	7.30	23.00	3.60
" "	" "	Mack	7.00	24.00	3.60
Inbound "	2 Horse		7.50 H	21.00	3.50
" "	2 "		7.33	24.75	3.50
" "	2 "		5.75	22.00	4.00
" "	2 "		7.25	26.00	3.17
" "	2 "		7.60	25.70	3.00
" "	2 "		6.60	26.00	3.50
" "	2 "		5.90 H	24.40	3.20
Outbound "	2 "		6.80	25.00	3.40
" "	2 "		6.80	26.00	3.80
" "	2 "		6.50	26.00	3.60
" "	2 "		7.20 H	26.00	3.20
" "	2 "		7.40	25.50	3.00
" "	2 "		6.50	25.70	3.50
" "	2 "		6.20	24.00	3.70
" "	2 "		6.30	25.50	3.60
" "	2 "		6.20	24.00	3.00
" "	2 "		7.00	25.00	3.40
" "	2 "		7.00	24.60	3.00
Inbound "	1 "		5.75	21.17*	3.50
" "	1 "		5.83	21.00	3.50
" "	1 "		5.60 H	24.40*	3.60
Outbound "	1 "		6.50	27.00	4.00

SUMMARY OF ALL VEHICLES

Type	Number of Vehicles	Average Width	Average Length	Average Height to Bed
Motor Trucks	25	6.45′	20.51	3.54′
2 Horse	18	6.77	25.01	3.39
1 Horse	4	5.92	23.39	3.67
	47	6.53	22.48	3.50

NOTE: Extreme width, unless otherwise noted, gives width of wagon bed in feet.
H—Indicates width over hub caps in feet.
*—Indicates over all length to head of horse in feet.

From this data it may be observed that the average length of all vehicles measured was 22.48 ft. with a maximum of 27 ft., and that the average width of all vehicles measured was 6.53 ft. with a maximum of 7.6 ft.

It may be further observed that the average length and width of horse drawn vehicles is considerably greater than that of motor trucks. Inasmuch as horse drawn vehicles still function to a large degree in the hauling of freight and will probably continue to do so for many years to come, it seems proper that the space provided per vehicle should be somewhat larger than the average vehicle dimensions noted above, and it is suggested that an arbitrary length and width of 25 ft. and 8 ft., respectively, be used in computing the width of roadway required. In the discussion which follows all vehicles will be assumed to occupy a position at right angles to the tailboard. A saw tooth tailboard arrangement wherein the vehicle backs against tailboard at an angle other than 90 degrees has been used at a number of recent freight houses, but will not be included in this discussion owing to lack of data pertaining to definite operating advantages found at these houses as a result of its use.

If the roadway is to serve a house on one side only, it is apparent that after allowing two lanes of travel, each 8 ft. wide and a vehicle space length of 25 ft., that a width of 41 ft. will be required.

If houses on both sides of the roadway are to be served there should be provided wherever possible two lanes of travel each 8 ft. wide and a vehicle space length of 25 ft. each for two vehicles placed in juxtaposition, thus giving a roadway 66 ft. wide. While this width cannot always be obtained, a roadway not less than 60 ft. appears to be the minimum which should be provided if local conditions will permit. If the roadway is obstructed by columns a reasonable increase in width should be made.

In support of the above data it is interesting to note that in an investigation of a number of existing freight houses it was found that widths of 27 ft. to 50 ft. have been used for roadways serving houses on one side only. Where houses are served on both sides of the roadway the same investigation shows that widths from 58 ft. to 74 ft. have been used.

Width of Occupancy Per Vehicle Against Tailboard.

Table No. 2 gives the result of observations made recently to determine this factor. From this data it may be observed that the average width of occupancy was 8.82 ft. and that 72 per cent of the vehicle groups observed averaged between 8 ft. and 10 ft. In an article describing the recent New York Central freight terminal in Cleveland (Engineering News, Vol. 82, pages 508 to 510), it is stated that a door spacing 10 ft. center to center, each door serving one vehicle, was used. Based on the above data and information it would appear that a width of 10 ft. to 12 ft. should be sufficient for this factor.

TABLE 2—WIDTH OF OCCUPANCY PER VEHICLE

Data Obtained From Observations Made at I. C. R. R. South Water Street Freight Terminal, Chicago, September 14-15, 1921

Location	Number of Vehicles	Aggregate Width	Average Width Per Vehicle
Inbound House	6	55.0	9.17
" "	6	60.0	10.00
" "	2	18.0	9.00
" "	3	25.0	8.33
" "	4	34.5	8.63
" "	2	16.0	8.00
" "	3	22.5	7.50
" "	5	37.5	7.50
" "	2	20.0	10.00
" "	4	30.6	7.65
" "	2	16.3	8.15
" "	3	28.0	9.33
" "	3	26.4	8.80
" "	4	36.6	9.15
" "	3	31.5	10.05
" "	3	28.2	9.40
" "	5	42.0	8.40
" "	2	19.2	9.60
" "	2	16.0	8.00
" "	3	24.1	8.03
" "	5	41.2	8.24
" "	2	17.4	8.70
Outbound "	2	19.0	9.50
" "	2	19.5	9.75
" "	2	20.8	10.40
TOTALS....	80	705.3	

Average width of occupancy per vehicle $\frac{705.3}{80} = 8.82$ ft.

Range: From 7.50 ft. to 10.40 ft.

Between 7 ft. and 8 ft................. 3 groups = 12%
Between 8 ft. and 9 ft.................10 groups = 40% } 72%
Between 9 ft. and 10 ft................. 8 groups = 32% }
10 ft. and over ....4 groups = 16%

25 groups 100%

Speed of Vehicles Along Roadway.

This information, shown in Table No. 3, is necessary in order to determine the loss of time incident to the travel of a vehicle along the roadway while en route to the tailboard. It is of interest to note that the speed of horse drawn vehicles is almost exactly one-half that of motor trucks. Owing to the increasing preponderance of motor trucks in use for hauling freight, it is felt that a speed somewhat higher than the average of 7.04 M.P.H. might well be adopted and a speed of 8 M.P.H. is suggested. It should be observed that this factor need be considered only in the case of long houses.

TABLE 3—SPEED OF VEHICLES

Data Obtained From Observations Made at the I. C. R. R. South Water Street Freight Terminal, September 15, 1921

Location	Type of Vehicles	Speed Miles Per Hour
Outbound House	Motor Truck	8.57
“ “	“ “	7.50
“ “	“ “	10.00
“ “	“ “	9.67
“ “	“ “	8.11
“ “	“ “	13.04
“ “	“ “	8.82
“ “	“ “	10.00
“ “	“ “	8.33
“ “	“ “	13.63
“ “	“ “	13.04
“ “	“ “	10.71
“ “	“ “	6.12
“ “	“ “	10.33
“ “	“ “	12.50
“ “	“ “	9.09
“ “	“ “	12.50
“ “	“ “	14.29
“ “	“ “	12.00
“ “	“ “	8.11
“ “	3 Horse Wagon	3.95
“ “	2 “ “	3.33
“ “	2 “ “	3.22
“ “	2 “ “	3.66
“ “	2 “ “	3.33
“ “	2 “ “	5.00
“ “	2 “ “	7.32
“ “	2 “ “	3.66
“ “	2 “ “	5.88
“ “	2 “ “	4.69
“ “	2 “ “	6.82
“ “	2 “ “	6.38
“ “	2 “ “	4.47
“ “	2 “ “	3.80
“ “	2 “ “	4.47
“ “	2 “ “	3.75
“ “	2 “ “	3.37
“ “	2 “ “	7.32
“ “	2 “ “	3.90
“ “	2 “ “	3.90
“ “	2 “ “	3.62
“ “	2 “ “	3.75
“ “	2 “ “	3.66
“ “	1 “ “	6.67
“ “	1 “ “	4.05
“ “	1 “ “	6.67
“ “	1 “ “	7.50
“ “	1 “ “	3.26
“ “	1 “ “	5.36
“ “	1 “ “	7.14
“ “	1 “ “	9.09

Average speed for motor trucks....10.32 miles per hour
Average speed for 3-horse wagon.. 3.95 miles per hour
Average speed for 2-horse wagons... 4.50 miles per hour
Average speed for 1-horse wagons.. 6.22 miles per hour

Average speed for all vehicles...... 7.04 miles per hour

Average Loading Per Vehicle in Tons.

It has been found that the average loading in tons per vehicle used in hauling inbound freight is not the same as that for outbound freight. Recent observations at a Chicago freight house show the average loading per vehicle to be 1.41 tons at the inbound house and 1.30 tons at the outbound house. These figures are merely submitted as information and direct observation should be made in each particular case, although they probably closely approximate the general average found in large cities where regular transfer companies are established.

Average Loading Per Car in Tons.

This factor is subject to such wide variation that the car loading found at one freight house can rarely be used in designing a proposed house. This factor is directly affected by local conditions, classification of freight, car shortage and other items, and should be ascertained by careful study of records in each particular case.

Average Time of Loading or Unloading Per Vehicle.

This factor affects the design of both inbound and outbound houses and is largely influenced by operating conditions. Adequate facilities for calling, checking, routing and weighing freight assist materially in a reduction of this factor and should be closely studied in this connection. At one freight house in Chicago, it was found that the average time required to actually load a vehicle at the inbound house is 35 minutes and that the average time required to actually unload a vehicle at the outbound house is 18 minutes. These figures are based on a two-week study and while they probably approximate average conditions, they should not be used without corroboration for actual design purposes.

Rate of Turnover of Freight Received in Inbound House and Relation to Floor Space Required.

So far as known to the Committee, no observations have been made to determine the rate of turnover at inbound houses except those made at the Illinois Central house at South Water Street, Chicago. At this house it was found that the freight moving out of the house by means other than door is subject to a delay of 24 hours or less while freight delivered through door to consignee and connections is subject to an average delay of approximately three days. Obviously it is important to determine what per cent of the total turnover is delivered to consignee direct. In the absence of supporting data, the value given above will be used in what follows as a basis for developing the ratio between turnover and tonnage handled daily subject to delay.

From Figure 1 it may be observed that where freight is subject to a delay of 24 hours or less, space need be provided only for the daily tonnage received and that the space required to store freight subject to delay greater than 24 hours is a direct function of the rate of turnover.

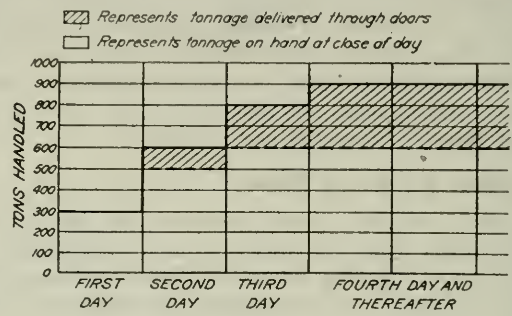

Fig. 1

Showing relation between inbound tonnage received and tonnage on hand; based on a house with an assumed average daily door business of 300 tons and a three-day turnover.

This figure also indicates that with a three-day turnover and a daily business of 300 tons the tonnage for which floor space must be provided is 600 tons or twice the daily tonnage received, and that this will be a constant amount after the fourth day. A similar analysis may be made for any other rate of turnover.

Floor Area Required Per Ton of Inbound Freight.

While this factor is somewhat dependent upon the specific character of freight handled, a general value may be deduced which represents average conditions.

The average merchandise car is 8 ft. by 38 ft. inside dimensions or 304 sq. ft. in area. Assuming as a basis for analysis that the loading is eight tons, we have 38 sq. ft. net per ton of miscellaneous freight. Due to separation of the several consignments when placed in the house, it is rarely possible to pile the freight on the floor as high as in the car. High piling on the floor is neither advisable nor desirable, accessibility being essential to satisfactory and economical house operations. Observations show that the space required on the floor is substantially twice that required in the car. This gives 76 sq. ft. of net floor area per ton of miscellaneous freight placed in the house. At the South Water Street inbound house of the Illinois Central Railroad it was found that only 70 per cent of the inbound freight goes out through the doors and is, therefore, subject to delay. Applying this factor of 70 per cent gives 53.2 sq. ft. net floor area per ton of miscellaneous freight received per day. In the study of Rate of Turnover it was shown that an average delay to freight of three days results in the necessity of providing floor space for twice the average tonnage received daily subject to delay. Applying this factor gives an area of 106.4 sq. ft. net floor space required per ton of miscellaneous freight. To determine the gross floor area, it will in every instance be necessary to determine the area required for trucking aisles, toilet facilities, office space, rest rooms, etc. In a properly designed house this should not exceed 33⅓ per cent of the total house area. Using this figure as a basis gives 159.6 sq. ft. of gross floor area required per ton of miscellaneous freight received per day. It should be noted that this value is predicated on the assumption that only 70 per cent of all inbound freight is placed on the house floor for delivery through the doors. If 100 per cent of all freight moves out in this manner, 216 sq. ft. are required. These figures perhaps more properly apply to the larger terminals since conditions at the small freight house at local points are usually such that all freight moves through the doors and with considerable rapidity. In the article, previously mentioned, describing the New York Central freight terminal in Cleveland, it is stated that 150 sq. ft. floor area per ton of freight was assumed in the design.

In an article written by Mr. Henry A. Goetz, which appeared in the Railway Age Gazette, Volume 61, page 460, a gross area of 150 sq. ft. is also recommended. At the Illinois Central Railroad's South Water Street inbound house it was determined that the tonnage resulting in the most efficient operation of the house equates to a value of 145.6 sq. ft. gross floor area per ton of freight received subject to delay.

Using the above data as a guide and observing its limitations, it is suggested that a gross area of 150 sq. ft. per ton of miscellaneous freight subject to delay be used, unless actual investigations of the classification, percentage delivered through doors, car loading or rate of turnover dictate a revision of the assumptions made.

Floor Area Required Per Ton of Outbound Freight.

This factor is influenced by the general method of operation in the house, such as use of two wheel trucks, four wheel trucks and motor trains; also by the necessity for providing storage space for freight on the floor in houses where "sailing days" are observed. This factor is also influenced by the length of the house.

In the article by Mr. Goetz noted above, it is recommended that the width of an outbound house should be such as to allow 40 sq. ft. per ton of freight handled and should in general be 30 ft. wide. For small freight houses in which hand trucking is used exclusively this probably is sufficient, but a width of 40 ft. and upward, dependent on proposed plan of operation, should be provided for houses in which general use of motor trains will be made.

Floor Area Required for Storage of Outbound Freight.

This factor is largely influenced by the relations between the hour all stowing in cars is stopped and the closing hour of the house. Often this is one hour or more and it is obvious that considerable freight will accumulate during this period which must be stored over night on the floor of the house.

In houses which operate partly on a "sailing day" plan, it is clear that a very material tonnage may accumulate, especially when shipments are made only once or twice a week, and this must also be provided for. No definite recommendation can be made to provide for such tonnages and careful study should be given this question. Perishables, when handled, require careful attention and cooling or warming facilities of ample proportion should be provided.

Peak Vehicle Loads—Inbound and Outbound House.

An investigation made during the past year clearly shows that there are two distinct peaks during the day, one occurring in the forenoon and the other in the afternoon. These peaks are shown in Figures 2 and 3.

From an inspection of these curves it is evident that figures based on maximum tailboard capacity are of little value and that the average occupancy of the tailboard during the entire day governs the daily house capacity from a door standpoint.

A study of these curves indicates that the ratio of the daily average tailboard occupancy to the maximum tailboard capacity is 70 per cent for the inbound house and 60 per cent for the outbound house. These ratios, or their equivalent based upon actual operation at a particular house, must be taken into consideration in determining the daily average house capacity and length of tailboard required per ton of door freight or per car.

From a study of the influences which govern the fluctuation in number of vehicles occupying tailboard space simultaneously during any particular period of the day, it is believed that the data reflected by these curves very closely approximates average conditions found at nearly all freight houses.

Average Tonnage Which Can Be Handled Per Day Per Lin. Ft. of Tailboard and Per Door.

Inbound House.

In a preceding paragraph it was stated that the average unloading time per vehicle was found to be thirty-five (35) minutes. Using this figure for the purpose of discussion and adding for other losses of time due to usual causes, results in the following basis for analysis:

Average time required to actually load a vehicle.....	35 minutes
Average time required to pay freight bill, reach position against tailboard and obtain service of truckmen	10 minutes
Total per vehicle load..........................	45 minutes

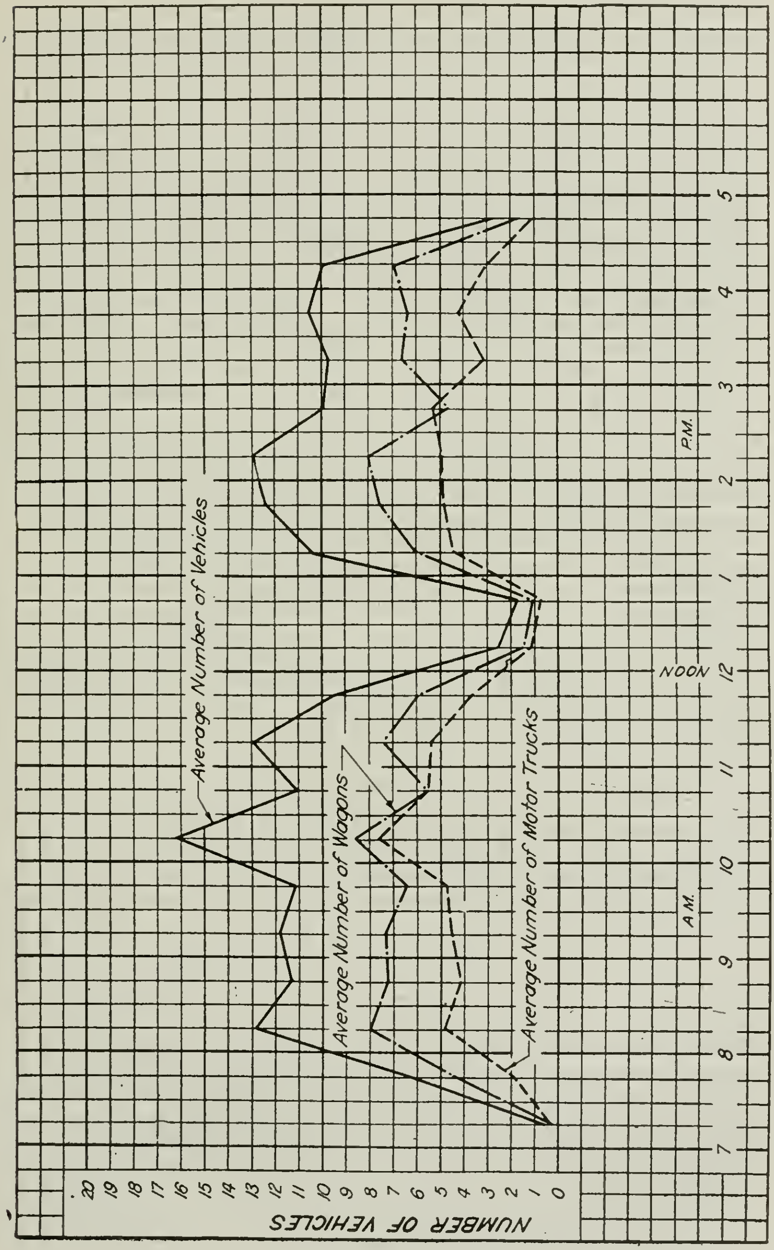

Fig. 2—Showing Average Number of Vehicles Arriving at Inbound House.

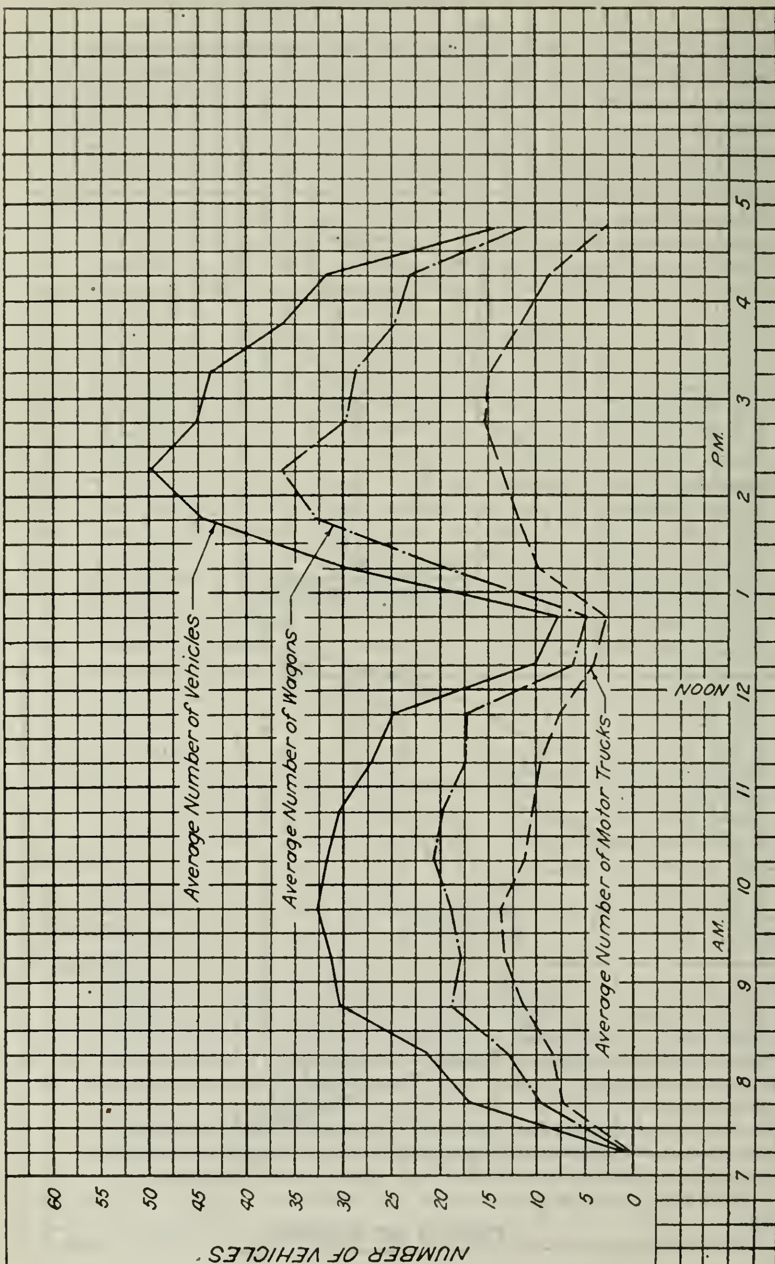

Fig. 3—Showing Average Number of Vehicles Arriving at Outbound House.

Applying the factor of tailboard occupancy noted in the preceding paragraph and assuming a loading per vehicle of 1.43 tons and a vehicle space 11 ft. wide gives $\frac{1.43}{11} \times \frac{60}{45} \times 70$ per cent or 0.121 tons per lin. ft. of tailboard per hour. This is equivalent to 1.21 tons per 10-hour day or 13.31 tons per vehicle space per day. In the article describing the New York Central freight terminal at Cleveland, it is stated that 13½ tons per door per day were actually being handled prior to its reconstruction, but that for the purpose of design, a value of 15 tons per door per day was used. From the close agreement in the above figures it would appear that from 13 to 15 tons per day can be handled per vehicle space. If the spacing of doors is equal to the assumed vehicle space it follows that a like tonnage can be handled per door per day.

Outbound House.

The same method of analysis given for the inbound house will now be applied to obtain values for the outbound house:

Average time required to actually unload a vehicle...	18 minutes
Average time required to reach position against tailboard, obtain service of truckman, and to check, weigh and route freight...........................	16 minutes
Total per vehicle load...........................	34 minutes

Assuming a factor of tailboard occupancy of 60 per cent, a loading per vehicle of 1.3 tons and a vehicle space 11 ft. wide gives

$\frac{1.30}{11} \times \frac{60}{34} \times 60$ per cent or 0.125 tons per lin. ft. of tailboard per hour.

This is equivalent to 1.25 tons per lin. ft. of tailboard per 10-hour day or 13.75 tons per vehicle space per day.

From a comparison of the values shown above, it would appear that the average daily capacity per lin. ft. of tailboard per day per vehicle space or per door is substantially the same for both inbound and outbound houses.

Tailboard Required Per Car.

Inbound House.

In the foregoing discussion it was shown that 1.21 tons of freight can be handled per lin. ft. of tailboard per 10-hour day. It is important at this time to determine the percentage of inbound freight which is delivered through the doors direct to consignee or connecting lines and that delivered by cars or other means. At the South Water Street inbound house of the Illinois Central Railroad it has been determined that 70 per cent of all inbound freight moves through the doors. Similar data for other houses is not available, therefore this percentage will be used here as a basis for analysis. Assuming one car setting per day and a car loading of 8 tons results in $.70 \times 8 = 5.6$ tons of door delivered freight per car and $\frac{5.6}{1.21}$ equals 4.64 lin. ft. of tailboard per car. If the house handles 100 per cent door freight, 6.63 lin. ft. of tailboard space is required per car. This value is not susceptible to general application owing to the wide variation in the proportion of freight delivered through the doors and in car loading, but the analysis shown above will serve as a basis and can be modified to suit any particular case.

Outbound House.

A value for the outbound house can be obtained in a similar manner. At the South Water Street outbound house of the Illinois Central Railroad at Chicago, it has been found that 40 per cent of all outbound freight is received through the doors. Assuming one setting per day and an average car loading of 8 tons results in $.40 \times 8 = 3.2$ tons of door freight per car. It was shown under tailboard capacity that 1.25 tons of freight can be handled per lin. ft. of tailboard per 10-hour day. Applying this value we obtain $\frac{3.2}{1.25}$ or 2.56 lin. ft. of tailboard required per car. If the house handles 100 per cent door freight, 6.4 lin. ft. of tailboard space is required per car. This value is based on specific conditions and should be modified if actual data is available and is found to disagree materially with the assumptions made.

Number and Spacing of Scales.

Inbound House.

There are in general use at the present time two distinct types of freight house scales—the beam scale and the dial scale. For general purposes, the dial scale of 4 to 5 tons capacity has some advantage, owing to the rapidity with which shipments can be weighed. For heavier loads, such as machinery and steel, the beam scale is more generally used. The capacity and style of scale to be used is largely dependent upon the character and volume of freight normally handled through the house. A few scales of greater capacity should be provided to permit weighing of heavy shipments.

In recent years there has been a growing tendency to weigh a part or all inbound freight received, or at least such consignments whose billed weight appears suspicious. Admittedly, re-weighing is a heavy item of expense, but it is undoubtedly a profitable operation if exercised judiciously. In numerous cases such re-weighing has doubled and trebled the freight revenue on the shipments in question, thus leaving little doubt as to its desirability.

Table No. 4 reflects past practice in re-weighing inbound freight at various freight houses built within recent years.

TABLE NO. 4—DATA ON SCALES USED AT VARIOUS FREIGHT HOUSES

INBOUND HOUSE

Name of Railroad	Location	No. of Scales	Spacing of Scales	Cars Per Scale
Soo Lines	Chicago	6	60 feet	11.7
C. & A. R. R.	"	10	80 "	6.8
P. R. R.	"	7	200 "	22.2
C. B. & Q. R. R.	"	7	100 "	22.4
Great Northern R. R.	St. Paul	9	80 "	9.4
O. W. R. R. & N. Co	Portland	4	126 "	7.5
"	Seattle	13	40 "	2.2
N. Y. Central	Cleveland	6	230 "	9.3
St. L. S. W. R. R.	St. Louis	2	56 "	4.5
C. G. W. R. R.	St. Paul	10	36 "	3.2
Erie Railroad	Akron	1	....	40.0
P. R. R.	Indianapolis	4	200 "	23.7
Pere Marquette R. R.	Chicago	2	120 "	10.5
Southern R. R.	Cincinnati	5	135 and 150 "	5.2

Outbound House.

Practically all freight received through the door is weighed upon receipt. To handle the door freight offered during rush periods requires that an ample number of scales be provided. Observations indicate that one scale every 44 ft. is ample, which, based on a door spacing of 11 ft. results in one scale every fourth door. Table No. 5 reflects data in this respect and was secured from a study of a number of the more important outbound houses built throughout the country within recent years.

TABLE NO. 5—DATA ON SCALES USED AT VARIOUS FREIGHT HOUSES

OUTBOUND HOUSE

Name of Railroad	Location	No. of Scales	Spacing of Scales	Cars Per Scale
Soo Lines	Chicago	15	30 feet	5.9
C. & A. R. R.	"	14	40 "	9.5
P. R. R.	"	28	50 "	7.1
C. B. & Q. R. R.	"	40	44 "	5.7
O. W. R. R. & N. Co	Portland	13	36 "	4.2
"	Seattle	4	40 "	1.25
New York Central	Cleveland	24	40 "	7.0
St. L. & S. W. R. R.	St. Louis	11	54 "	3.0
Erie Railroad	Akron	7	47 "	2.0
P. R. R.	Indianapolis	17	32 "	8.0
Pere Marquette R. R.	Chicago	5	60 "	7.2
Southern R. R.	Cincinnati	12	60 "	2.1

Spacing of Doors.

Careful study of this question would seem to indicate that the door spacing should be a multiple of the vehicle space adopted in determining the tailboard capacity. As previously stated, this width should be between 10 and 12 ft. If two vehicle spaces are provided in each panel of the building, this results in a panel length of 20 to 24 ft. and gives an economic building design from both an operating and a structural standpoint.

Another equally important point to observe is the relation between the average car length and panel length of the building. On account of the variation in length of cars commonly used, there is generally some loss of track capacity experienced due to spotting cars opposite door openings and the panel length adopted should be such as will result in a minimum door loss.

Where local conditions permit at the inbound house a trucking platform of suitable width between the house and tracks should be provided. With such an arrangement there is no door loss occasioned by spotting cars and transfer of freight from car to house or car to car can be accomplished in a very expeditious manner. Such a platform is also very desirable on the delivery side of inbound houses. At the outbound house there is generally no advantage to be gained in providing such platforms.

Economic Length of House.

Where hand trucking is resorted to, previous investigations of economical operation indicate that the maximum length of house should be about 500 ft. If motor train operation is used, the length of house should not materially exceed 1,200 ft. An excellent reference on this subject may be found in a paper entitled "Notes on LCL Freight Houses," by Mr. E. H. Lee, Vice-President of the Association, Vol. 15, page 364. This paper deals with the economics of handling freight by hand and by motor train and is a valuable contribution to the scant literature on this subject. As a result of the study made in connection with the design of the New York Central freight facilities at Cleveland (Eng. News, Vol. 82—pages 508 to 510), it was decided that 1,250 ft. is the approximate maximum length of house which should be built consistent with economic freight handling, using motor train operation.

Floor Live Loads Per Square Foot.

The live load per square foot for which Inbound freight house floors should be designed is somewhat dependent upon the character of freight handled. In a previous paragraph it was stated that a ton of inbound freight piled on the floor occupies 76 sq. ft. This gives a load of 263 pounds per sq. ft. of loaded area. Some allowance must be made for impact and for concentrated loads. It is suggested that a live load of 250 to 300 pounds per sq, ft. be used for designing the floor framing unless local conditions dictate otherwise. At the Outbound house, the question of floor load is not so important, as the freight is kept moving, but it seems advisable that framing should be designed to carry about 250 pounds per sq. ft.

Summary.

In treating a subject so greatly influenced by variables as the design of freight houses, it is extremely difficult to formulate ironclad rules or to set up exact factors of design. A close analytical study should be made of past business, especially in the design of larger freight terminals, and much thought should be given to the probable growth of business. In general the design of a new freight house will involve the following steps and the study should be carried on in a logical manner and in approximately the sequence indicated below:

1. Make a critical study of the business to be handled. Ascertain the relation of each class of freight to the total tonnage handled.

2. Study past business for a sufficient number of years to determine the general trend of each class. Analyze the factors which govern and carefully consider the influence of each on probable future growth. Summarize and set up the data as a basis for design.

3. Obtain as much data as possible relating to all the factors of design enumerated in this report, bearing in mind the particular requirements of the freight house to be designed. Check up local conditions and compare the results with the factors indicated in this report.

4. Study the peculiarities of the proposed site to determine the most desirable size, shape and location of house as well as the most advantageous arrangement of approach and storage track.

5. Arrange all tracks so that the most flexible operation possible will result. Reduce switching movements to a minimum.

6. For preliminary design, pending further investigation, or in cases where detail information is not available, the following factors are suggested as a basis:

a. Roadway 40 ft. wide if one house only is served.

b. Roadway 60 ft. wide if houses on both sides are to be served.

c. Roadway 64 ft. wide if houses on both sides are to be served and column obstructions are encountered.

d. Eleven (11) ft of tailboard space per vehicle.

e. An average vehicle speed of 8 M. P. H.

f. In large cities, the existence of regular cartage companies operating vehicles to and from the freight houses probably results in a higher average vehicular loading since the average loading of such vehicles is generally 2 tons or over, while that for ordinary vehicles is frequently less than 1 ton. It, therefore, follows that the average loading for all classes of vehicles in use at a particular house is a function of the proportion of heavily and lightly loaded vehicles and that an absolute value to cover this factor cannot be set up. The values indicated in this study are merely submitted as information.

g. The loading per car can generally be ascertained from the records and should be obtained in each instance. In the absence of definite data the use of 8 or 9 tons per car for Inbound and Outbound freight will probably be found satisfactory.

h. The average time of loading or unloading per vehicle is a direct function of house operation and local condition. For freight houses in large cities, use the units given in this report. In smaller cities this factor should be investigated, together with the data indicated in item f.

i. One hundred fifty (150) sq. ft. of floor area per ton of miscellaneous inbound freight, subject to delay, will probably be found satisfactory, although local conditions may dictate otherwise.

j. Forty (40) sq. ft. of floor space for outbound freight received via doors or handled on the floor of the house, providing hand trucking is in use, will probably meet most needs. If motor trains are used as a means of handling freight to the cars, the width of house will be determined by its plan and the proposed method of operation. In such cases a width of 40 to 60 ft. appears desirable. If part of the outbound freight is handled on a separate transfer platform adjacent to the outbound setting a platform width of not less than 20 ft. for hand trucking and 30 ft. for motor operation appear desirable.

k. If the conditions are as outlined in this study 1.2 tons per linear ft. as the average daily capacity of the Inbound house tailboard for freight houses located in large cities may be used. Modify, if necessary, on the basis of data obtained under items f and h.

l. If the conditions are as outlined in this study, 1.25 tons per linear ft. of tailboard at the outbound house may be used. Modify according to items f and h if revision is indicated by local condition.

m. Tailboard frontage per car for either Inbound or Outbound house is not generally a limiting factor, although special cases may arise requiring a consideration of this factor.

n. Provide an adequate number of scales in the Inbound house to properly handle such reweighing as in the judgment of operating officials is necessary. There can be no argument that some reweighing is necessary and a check of shipments for a short period, say one week, at the existing facility or one of similar character will serve as an excellent guide in determining the number of scales required. At the Outbound house, one scale every forty-four (44) ft. appears to give satisfactory operation.

o. Generally speaking, limit the length of house for hand trucking to 500 ft. and for motor train operation to 1,200 ft. The proposed method of operation should be closely studied in this connection.

p. Minimum floor liveloads in large cities are generally controlled by municipal regulations, but it will be frequently found that the minimum floor load specified is inadequate. Unless the class of freight handled dictates otherwise, the floor load recommended in this report may be used as a basis for design.

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Appendix E

STANDARDIZATION

G. A. Rodman, *Chairman;* R. V. Reamer, F. M. Davison, *Sub-Committee.*

WINDOW GLASS SIZES

Replies to questionnaires sent out would indicate very little has been done on many of the railroads in regard to standardization of window glass sizes.

Two or three roads have adopted one standard for all purposes—this being a light 10 in. by 16 in. in size. A few additional roads have adopted a standard for some of the minor types of buildings.

It is the opinion of the Committee that it would be a practical impossibility to adopt one size of window glass which would answer for all types of buildings and for all sections of the country, but we do believe that standard size can be adopted for all roads for such buildings as shops, engine houses, yard buildings, minor passenger stations and freight houses; also all of the small miscellaneous buildings on the railroad. When it comes to elaborate city stations, general office buildings, and the larger city freight offices, it is desirable, for architectural effects, to use larger sizes of glass. Further, in the second story of signal towers it is practically necessary to put in larger lights so as to give an unobstructed view of the tracks.

The question of sizes and prices was taken up with window glass manufacturers and they recommended, first, all fractional sizes to be eliminated—this will save the fractional cutting charge. They further recommend that as far as possible small sized glass be used, as this tends to reduce the cost per square foot of glass. At the present time a 10 in. by 16 in. light costs about twelve cents (12c), and as the size increases the price per square foot increases, so that when we get to 20 in. by 32 in.—which is four times as large, the price is five times the cost of 10 in. by 16 in.—or an increase of 25 per cent.

In view of these facts it would seem desirable to adopt a light 10x16, or about that size, for all miscellaneous purposes, including shops, engine houses and country passenger stations. For the more elaborate buildings, usually designed by an architect or where it is advantageous to put in larger lights, to adopt certain standard sizes which best suit the conditions of the railroad. These sizes, so far as possible, to be multiples of 10x16. The number of sizes used to be reduced to a minimum to effect saving in the Stores Department stock and also the confusion arising from repairmen having to carry a number of different sizes of glass—also to avoid errors in taking measurements.

STANDARD FIRE HOSE

It seems to be a pretty general practice on the railroads of the country to use a 2½" hose, and most of the roads use double jacket cotton hose, rubber lined, for outdoor purposes.

This would seem to answer all requirements for outdoor use, as well as interior rooms which are not heated. Where rooms are artificially heated, rubber hose is not satisfactory, and unlined linen hose should be used. At points where there is only one man on duty at night, such as freight houses, shops, etc., and where the water pressure is high, it is desirable to have a small hose which can be handled by one man and for these points 1½" unlined linen hose is generally used.

NOZZLES

No particular type of nozzle seems to be common in the various parts of the country. It seems unwise to adopt one standard, as these nozzles are oftentimes made by local manufacturing concerns and of slightly varying dimensions and design.

The National Board of Fire Underwriters have a specification for nozzles as follows:

"(a) All 2½-inch fire hose should be provided with approved play pipes having a nozzle with 1⅛-inch discharge orifice. The play pipe should be attached to the hose and ready for use.

"(b) All 1¼ and 1½-inch fire hose should be provided with approved play pipes having a discharge orifice not less than ½-inch nor more than ¾-inch in diameter. Play pipes to be at least 8 inches in length, tapered, finished smooth on the interior and provided with a heavy outside bead at the discharge tip. They should be attached and ready for use."

If each railroad would adopt a standard for use, in general conforming to the Underwriters' specifications, to be made of brass for inside of office buildings, stations, etc., or of cast iron for outdoor use, such as freight houses, shops, and other exposed points, it would seem to be a satisfactory solution.

HOSE THREADS

The National standard thread for 2½" hose is 3 1/16" outside diameter male thread, 7½ threads to the inch. This standard is being adopted by many cities all over the country, and is also used by the majority of railroads, and the Committee feels that this will soon be a standard for all purposes. The old threads, which are not standard, can be either re-cut or replaced as soon as convenient, and where the local fire department has a different standard, the hydrant may be equipped with adapters; male thread to fit the local City standard, female thread to fit the National standard on the hydrant.

For 1½" hose there is no authorized standard at the present time, although the National Board of Fire Underwriters is working for a standard.

Various authorities are arguing between a standard of 11½ threads to the inch and one of 8 threads to the inch. Until something definite is decided, the Committee believes that no definite recommendation should be made for a thread for 1½″ hose.

FIRE HYDRANTS

It is the understanding of the Committee that we are only to consider hydrants suitable for railroad yard purposes and not hydrants for use on streets adjacent to railroad yards, as the latter are usually furnished by the city in accordance with their local standards.

The National Board of Fire Underwriters have made up certain recommendations for fire hydrants and a copy of their revised specifications are attached. Fire hydrants are generally made up by some local manufacturing firm in the vicinity of the railroad which uses them; the result is that while they may conform to a specification there are many minor variations in design.

A hydrant for miscellaneous yards is usually equipped with two 2½″ hose connections for National standard thread, one 4″ steamer connection with thread to fit local city standard. Water supply connection to be at least 6″. In location where there is no call for steamer connection it can, of course, be omitted.

The Committee recognizes the fact that in large cities, particularly at docks and large freight terminals, it may be desirable to install larger size hydrants. Each special case of this kind should be treated on its merits, and we believe in general hydrant installed should be one to fit local city standard, as these special points are usually under the jurisdiction of City Department and only city fire hose likely to be used.

For hydrant located inside of buildings, general practice is to use a standpipe composed of standard 3″ extra heavy galvanized iron pipe with a 2½″ connection—National standard thread controlled by proper gate valve. Where conditions of water supply, pressure, etc., warrant it, smaller standpipe, say 2″ equipped with 1½″ hose connections are desirable.

REPORT OF COMMITTEE XVII—ON WOOD PRESERVATION

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Committee.

To the American Railway Engineering Association:

Your Committee on Wood Preservation respectfully submits its report on the following subjects:

(1) Revision of the Manual

Proposed changes or additions to the Manual are indicated by underscored lines in the appendices.

In Appendices A, F and G the Committee submits changes and additions covering the following items and recommends their adoption under the heading of "Conclusions."

(a) Revised specification for Preservative Treatment of Wood with Creosote Oil (Empty Cell Process with Final Vacuum).

(b) New specification covering Preservative Treatment to be used on Piles and Timbers in Land Construction.

(c) New specifications covering Methods for Storing Lumber and Piling for Air-seasoning Preliminary to Preservative Treatment.

(2) Service Records

In Appendix B the Committee submits tables indicating the life of ties treated with zinc, zinc creosote and creosote, taking as a basis the service life of ties of the different kinds of woods in various sections of the country. Also, the Committee makes definite recommendations covering the selection, installation and record of test sections.

(3) Preservative Treatment for Douglas Fir

In Appendix C the Committee submits as information the results received to date covering the experimental treatment of Douglas Fir after perforating, and as a result of these experiments the Sub-Committee in charge strongly recommends at this time that ties to be treated with zinc chloride be perforated previous to treatment.

(4) Treatment of Piles and Timbers for Marine Structures

In Appendix D the Committee on Pacific Coast Marine Piling gives the history of the protection that has been used in that territory, and also submits information concerning the biological phases of our problem together with records of some structures that have given excellent service in that district.

In Appendix E the Committee on Research covering Marine Piling gives a full report of the investigations that have been carried out in this country and abroad considering a problem that has come to the attention of Engineers the world wide.

(5) Preservative Treatment for Piles and Timbers in Land Construction

In Appendix F the Committee submits for adoption definite additions to the General Requirements, and which are recommended for adoption as Recommended Practice under the heading of "Conclusions."

(6) Methods for Storing Lumber and Piling

In Appendix G the Committee submits additions to the General Requirements and recommends them for adoption as Recommended Practice under the heading of "Conclusions."

CONCLUSIONS

Your Committee makes the following recommendations to the Association:

For adoption and publication in the Manual:

Subject (1)

(a) Revise specifications for the Preservative Treatment of Wood with Creosote Oil (Empty Cell Process with Final Vacuum).

(b) New specification for Preservative Treatment to be used on Piles and Timbers in Land Construction.

(c) New specification covering Methods for Storing Lumber and Piling for Air-seasoning Preliminary to Preservative Treatment.

Accept as information:

Subject (2) Report on Service Test Records.
Subject (3) Report on Preservative Treatment for Douglas Fir.
Subject (4) Preservative Treatment of Piles and Timbers in Marine Construction.

Recommendations for Future Work

The Committee recommends for future work continuation of Subjects Nos. (1), (2), (3), (4), and as new subjects:

(1) Present a report with reference to the Preservative Treatment of Groups UA and UB Ties.
(2) Prepare a map showing region where zinc chloride can be economically used.
(3) Prepare a report covering the proper preparation of timber before treatment which will include adzing and boring of ties.
(4) Effect of preservatives on inflammability of wood.
(5) Consider the desirability of treating bridge caps, stringers, bridge ties, and other bridge elements, except piling, with zinc chloride.
(6) Develop a proper indicator for determining the penetration of sodium fluoride in wood.
(7) Recommend preservative treatment for wood pipe staves.
(8) Recommend preservative treatment for signal trunking and capping.

Respectfully submitted,

THE COMMITTEE ON WOOD PRESERVATION,

C. M. TAYLOR, *Chairman.*

Appendix A

(1) REVISION OF THE MANUAL

C. M. Taylor, *Chairman*

The Committee has revised the specification for the Preservative Treatment of Wood with Creosote Oil (Empty Cell Process with Final Vacuum), as shown on page 332 of the 1920 Proceedings.

The third paragraph of the specification has been changed to read as follows:

"The material shall retain an average of at least 6 pounds of creosote oil per cubic foot which will permeate all of the sapwood and as much of the heartwood as practical," and no charge shall contain less than 90 per cent nor more than 110 per cent of the quantity per cubic foot that may be specified.

The specifications for creosote oils as now embodied in our Recommended Practice have been subject to some discussion during this past year, and a committee was appointed consisting of R. S. Belcher, H. C. Bell, C. E. Gosline and O. C. Steinmayer. As a result of an investigation covering forty-two different railroads using creosote oil, it was disclosed that a great many of the railroads are using oils which do not fully comply with our present specifications, and the following statement covering the situation has been approved by the General Committee as an indication of the situation:

"The specific gravities of the fractions are inserted as specified in Section five of the various creosote oil specifications to prevent the admixture of any considerable quantities of water gas tar. The limits had to be placed so high in order to prevent this that, as a general thing, the only oils that would meet the requirements are oils produced from coke oven tars and a few gas house tars that are produced under high temperatures and only moderate sized charges. The Committee now finds that a very considerable amount of creosote oil, that is apparently produced from authentic uncontaminated samples of coal tar, will not meet these gravity requirements. This is particularly so with a number of samples of English oils prepared from horizontal tars operated at moderate temperatures or at high temperatures with very large charges, or when produced from vertical retorts.

Furthermore, the Committee has recently been furnished samples of oil produced from the distillation of a petroleum tar that has gravities considerably in excess of those required. The Committee, however, is not in a position at the present time to recommend any simple test that will on the one hand absolutely prevent the addition of water gas tar and that will, on the other hand, permit the use of creosote oil made from all samples of coal tar.

The Committee, therefore, recommends that until the study now in progress by this Committee is completed and report thereon made that the railroads give greater consideration to the sources of tars used in the manufacture of creosote oil in case the specific gravities of the two fractions in question do not fully comply with our present recommended practice.

Appendix B

(2) SERVICE TEST RECORDS

R. H. Howard, *Chairman;* F. J. Angier, E. H. Bowser, S. D. Cooper, C. F. Ford, Hermann von Schrenk, *Sub-Committee.*

Instructions:

Make final report, if practicable, on Service Test Records, extending them to include treated timbers in Bridges, Docks and Wharves, and include a study of the records of service given by Zinc Chlorine Treatment.

Introduction:

The treatment of cross ties and timber of all kinds with some preservative to prevent decay, is growing more important as the available supply of timber decreases.

There are many different chemical preservatives used, and as creosote oil, zinc chloride, and a mixture of these two, are more widely used than the others, these only will be discussed in this report.

Of these preservatives there is no question about the use of creosote oil being preferable. Zinc chloride and a mixture of zinc chloride and creosote oil are used with much success in certain regions.

Treatment:

The attached statement "Exhibit A", supplied by the Forest Products Laboratory at Madison, Wisconsin, gives the results of all completed tests of cross ties of which we have record. There are other tests under way and the completion of these tests will add valuable data to that given in this exhibit.

The Committee is of the opinion that it will be much more desirable in the future to publish nothing but completed tests. It is considered that this is the best method to be used, as everybody interested will be able to get definite information as to service life secured in all parts of the country from cross ties treated by various methods. Completed tests will be reported each year.

Zinc Chloride (Burnettizing) Process:

With the present scarcity of creosote oil resulting in high prices, and the large number of cross ties to be treated, economy demands that some other preservative be used.

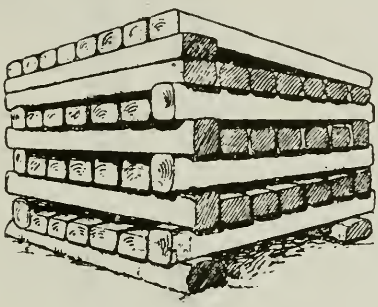
For some time there will not be sufficient creosote oil to treat the required number of ties. Therefore, it is imperative that the Burnett Process of treatment be more widely used in order to secure the greatest possible economy in the use of ties.

Below are given the governing features for maximum service life and economy in the use of ties treated by this process.

Conditioning required for satisfactory treatment:

(1) Preliminary seasoning—Be sure that the ties to be treated have been thoroughly seasoned and that decay has not already begun.

(2) Proper treatment—To secure this the treatment should be supervised by a competent Treatment Inspector under the jurisdiction of the Engineering Department of the Railroad.
(3) Subsequent seasoning—Care should be taken to see that the ties are thoroughly seasoned after treatment. They should be piled in close piles with end ties on edge (as per sketch below), to prevent excessive checking.
(4) All piles should be placed in dry places and kept free from weeds.



METHOD OF PILING TIES TREATED BY ZINC CHLORIDE. OUTSIDE TIES IN EACH COURSE LAID ON EDGE.

Maximum service results will be obtained only upon observance of the following:

(1) Drainage—Good drainage of the roadbed is absolutely necessary to secure maximum results.
(2) Ballast—The ballest should be sufficient and of the best available materials, and should be kept clean.
(3) Tie plates—Tie plates of proper size and thickness should be used on all treated ties to prevent destruction by mechaniical wear.
(4) Rail anchors—Use rail anchors where necessary to prevent creepage of rail, and slewing of ties.
(5) Distribution of ties—When practicable use hardwood ties on curves and softwood ties on tangents.
(6) Tie plugs—Whenever it is necessary to re-spike a treated tie, treated tie plugs should be applied, and when possible to do so the spike should be redriven into the tie plug.
(7) "S" Irons—"S" Irons should be applied to hardwood ties before treatment, preferably in the woods at time of manufacture, or, if not then, immediately after the inspection.

The following tables taken from "Exhibit A" indicate the life of ties, treated with zinc, zinc creosote and creosote, taking as a base the service life of ties of different kinds of wood in the various sections of the country. Attention is directed to the grouping of these tests. It will be noted that various methods of treatment are grouped according to the geographical location of the test and the kind of treatment given.

COMPLETED TESTS FROM THE RECORDS OF THE FOREST PRODUCTS LABORATORY, MADISON, WIS.

Zinc Chloride

Species	Railroad	Preservative Process	Absorption Lbs. per Cubic Ft.	Number of Ties	Territory	Traffic	Average Life—Years
Beech..........	G. C. & S. F........	Zinc Chlo. Burnett	....	99	Beaumont.........Tex.	Heavy	10.5
"	P. R. R............	"	....	13835	Western Division..Tex.	....	10.9
"	"	"	....	9937	Western Division..Tex.	....	11.1
Fir, Douglas....	S. P................	"	.243	217	Various Divisions .Cal.	Heavy	11.3
" " ...	"	"	.243	4043	" " "	"	10.9
" " ...	"	"	.243	1941	" " "	"	10.7
" " ...	"	"	.243	20536	" " "	"	10.9
" " ...	"	"	.243 *	12951	" " "	"	10.5
" " ...	"	"	.243	26146	" " "	"	9.2
" " ...	"	"	.243	43681	" " "	"	10.4
" " ...	"	"	.243	58983	" " "	"	10.2
" " ...	"	"	.243	48748	" " "	"	.97
" " ...	"	"	.243	44689	" " "	"	7.2
Gum, Red......	G. H. & S. A.........	"	.30	49	Bayview and St. Leon Tex.	"	8.9
" "	"	"	.30	34	" " "	"	7.3
" "	"	"	.30	32	" " "	"	9.3
" "	"	"	.27	44	" " "	"	8.8
" "	"	"	.27	45	" " "	"	7.0
Gum, Tupelo...	"	"	.234	30	" " "	"	8.0
" " ...	"	"	.234	33	" " "	"	7.9
" " ...	"	"	.224	46	" " "	"	7.0
" " ...	"	"	.224	37	" " "	"	7.0
" " ...	"	"	.224	30	" " "	"	7.0
" " ...	"	"	.234	22	" " "	"	7.2
Hemlock.......	P. R. R............	"	....	200	Western Division......	....	10.9
"	"	"	....	698	Chicago Division......	....	11.4
"	"	"	....	5909	Western Division......	....	10.2
"	"	"	....	4786	Chicago Division......	....	10.1
"	"	"	....	438	Western Division......	....	9.7
"	"	"	....	275	Chicago Division......	....	8.3
"	"	"	....	1000	" "	....	11.6
Hemlock.......	P. R. R............	Burnett	....	1048	Western Division......	....	9.8
"	"	"	....	521	" "	....	8.9
"	"	"	....	713	" "	....	9.2
Oak, Water.....	G. C. & S. F........	"	.26	100	Beaumont.........Tex.	Heavy	10.5
" "	"	"	.35	100	" .... "	"	6.8
Pine, Loblolly	"	"	.35	100	" .... "	"	9.0
" Lodgepole	U. P................	"	....	242000	Lines in Wyoming......	"	9.0
" "	"	"	.40	46	" Kansas........	"	16.0
" "	"	"	.40	26	" Kansas........	"	15.0
" "	"	"	.40	31	" Colorado......	"	14.8
" "	"	"	....	9	" Nebraska......	"	9.0
" "	"	"	.40	33	" Nebraska......	"	14.4
" Longleaf...	N. Y. N. H. & H....	"	....	57	Rowayton.......Conn.	"	13.0
" " ...	" ...	"	....	68	" .... "	"	14.4
" " ...	" ...	"	....	67	" .... "	"	14.8
" " ...	" ...	"	....	14	" .... "	"	12.8
" Sap.......	G. H. & S. A........	"	.412	334	" .... "	"	5.4
" "	"	"	.412	334	" .... "	"	5.5
" "	"	"	.412	333	" .... "	"	5.6
" Shortleaf..	G. C. & S. F........	"	....	100	Beaumont.........Tex.	"	10.0
" " ..	Sou. Pac............	"	.55	6048	Glidden District.. "	"	6.8
" " ..	"	"	.55	41691	San Antonio " "	"	8.2
" " ..	"	"	.55	15564	Del Rio " "	"	8.9
" " ..	"	"	.55	2607	Sanderson " "	"	6.7
" " ..	"	"	.55	12899	Valentine " "	"	7.0
" " ..	"	"	.55	13397	El Paso " "	"	7.5
" S. Yellow	A. T. & S. F........	"	.58	6357	Newton..........Kan.	15034755	T12.8
" "	U. P................	"	.40	5	Norfolk..........Neb.	Heavy	8.0
" "	"	"	.40	36	" .... "	"	10.0
" "	"	"	.40	81	" .... "	"	11.0
" W "	Gt. Nor.............	"	.50	2916	" .... "	"	13.2

Average life for 23 Test Sections in Texas....................................8.2 yrs.
" " 10 " " " California.....................................9.9 "
" " 12 " " " Pittsburgh-Chicago...................9.1 "
" " 7 " " " Connecticut..................................7.2 "
" " 6 " " Nebraska.....................................9.2 "

COMPLETED TESTS FROM THE RECORDS OF THE FOREST PRODUCTS LABORATORY, MADISON, WIS.

Zinc Creosote

Species	Railroad	Preservative Process	Absorption Lbs. per Cubic Ft.	Number of Ties	Territory	Traffic	Average Life, Years
Beech	G. C. & S. F.	Allardyce Zinc Creo.	3.0 Creo., 0.24 Zinc	50	Beaumont, Tex.	Heavy	8.9
"	"	...	0.3 Zinc, H'vy Creo.	50	" "	"	5.0
Gum, Red	G. H. & S. A.	Allardyce Zinc Creo.	0.27 Zinc, 4.49 Creo.	16	San Leon, Bayview, Tex.	...	10.4
" "	"	"	"	12	" " "	...	11.7
" "	"	"	"	17	" " "	...	10.4
Gum, Tupelo	"	"	0.22 Zinc, 2.02 Creo.	12	" " "	...	7.4
" "	"	"	"	14	" " "	...	10.0
" "	"	"		16	" " "	...	8.5
Hemlock	G. C. & S. F.	"	0.3 Zinc, H'vy Creo.	49	Beaumont, Tex.	Heavy	5.0
"	"	"	0.24 Zinc, 3.00 Creo.	50	" "	"	9.0
Oak, Red	G. H. & S. A.	Low Press.	...	250	Louisiana	"	10.5
Oak, Willow	"	...	0.24 Zinc, 3.00 Creo.	10	Beaumont, Tex	"	8.0
" "	"	Allardyce Zinc Creo.	0.3 Zinc, H'vy Creo.	11	" "	"	3.0
Pine, Loblolly	"	"	0.24 Zinc, 3.00 Creo.	49	" "	"	9.0
" "	"	"	0.3 Zinc, H'vy Creo.	49	" "	"	9.0
Pine, L. Leaf	"	"	...	50	" "	"	9.7
Pine, Sap	"	"	0.27 Zinc, 4.49 Creo.	127	Galveston, Tex.	...	8.3
" "	"	"	"	126	" "	...	10.4
" "	"	"	"	750	" "	...	11.1
Pine, S. Yellow	"	"	0.6 Zinc	189	Watkins Cut-Off, Tex.	...	14.0
" "	"	"	"	1085	" " "	...	15.6
" "	"	"	"	410	" " "	...	14.0
Tamarack	G. C. & S. F.	"	0.3 Zinc, H'vy Creo.	51	Beaumont, Tex.	Heavy	8.0
"	"	"	0.24 Zinc, 3.00 Creo.	50	" "	"	9.0

Average Life 23 Test Sections in Texas .... 12.5 years.

COMPLETED TESTS FROM THE RECORDS OF THE FOREST PRODUCTS LABORATORY, MADISON, WIS.

Creosote

Species	Railroad	Preservative Process	Absorption Lbs. per Cubic Ft.	Number of Ties	Territory	Traffic	Average Life, Years
Ash	C. B. & Q.	F. Cell	9.62	1	Lines West	...	9.0
Beech	P. R. R.	...	...	16	Western Division	...	9.8
Gum, Tupelo	G. H. & S. A.	F. Cell	13.2	23	Bayview, San Leon, Tex.	Heavy	13.6
" "	"	"	13.2	30	" " "	"	12.0
" "	"	"	10.9	35	" " "	"	10.9
Hemlock	N. Y. N. H. & H.	...	...	400	Medway, Mass.	"	20.0
Juniper	Norfolk Southern	F. Cell	8.0	25	Norfolk, Va., Division	...	15.4
"	" "	"	8.0	75	" " "	...	20.2
Oak, Red	P. R. R.	Reuping	...	9	Western Division	...	10 0
Pine, Loblolly	"	F. Cell	8-10	2743	Wooster, Ohio	20 million tons	6.4
Pine, So. Yellow	N. Y. N. H. & H.	...	...	200	Fair Haven, Conn.	...	11.0
" "	"	F. Cell	...	500	" " "	...	12.0
" "	A. T. & S. F.	Reuping	4.56	44	Sutton, Kan.	Heavy	13.8

From these tables we can estimate the probable length of life of ties manufactured from any wood treated with chloride of zinc for any section of the country. Using this life as a basis the annual cost may be figured from the current prices for materials and labor at any time by the application of the following formula for economic comparison of cross ties of different materials, taken from page 64, 1915 edition of A.R.E.A. Manual:

$$\text{Formula} - A \text{ (Annual Cost)} = \frac{CR(1+R)^n}{(1+R)^n - 1}$$

C = First cost of tie.
R = Rate of interest.
A = Annual Cost—Amount at compound interest which will provide for renewal at end of life of tie.
n = Life of tie in years.

It will take but a few moments of time to determine just how much one can afford to pay for a tie to be treated with zinc chloride to secure the estimated life. To serve as a guide the following example has been prepared:

Example for comparing the annual cost of untreated white oak tie with zinc treated red oak; zinc creosote treated red oak and creosote treated red oak tie:

Untreated white oak tie:

White oak tie, grade 3, cost	$1.10
Freight and handling	0.50
Insertion in track	0.40
Cost of tie in track	$2.00
Estimated life	6. yrs
Interest rate	6%
Annual cost of application of Formula	$0.41

Zinc treated red oak tie:

Red oak tie, grade 3, cost	$0.90
Freight and handling	0.50
.5 lb. zinc per cu. ft., 1⅓ lb. used, at 9c	0.12
Cost of treatment	0.19
Insertion in track	0.40
Cost of tie in track	$2.11
Estimated life	10 yrs.
Interest rate	6%
Annual cost by application of Formula	$0.29

Zinc creosote treated red oak tie:

Red oak tie, grade 3, cost	$0.90
Freight and handling	0.50
.5 lb. zinc per cu. ft., 1⅓ lb., at 9c	0.12
1 gallon creosote oil	0.12
Cost of treatment	0.19
Insertion in track	0.40
Cost of tie in track	$2.23
Estimated life	12½ yrs.
Interest rate	6%
Annual cost by application of Formula	$0.26

Creosote treated red oak tie:

Red oak tie, grade 3, cost	$0.90
Freight and handling	0.50
2½ gallons creosote oil used at 12c per gallon	0.30
Cost of treatment	0.19
Insertion in track	0.40
Cost of tie in track	$2.29
Estimated life	18 yrs.
Interest rate	6%
Annual cost by application of formula	$0.21

The prices used for the example represent current prices in St. Louis territory as of November, 1921. Each individual railroad can substitute its current prices in making comparisons of real cost of ties in its respective territory.

Rainfall Regions:

It is generally agreed that zinc chloride will give the best results in regions in which excessive rainfall is absent, and zinc chloride should not be used to treat cross ties when they are to be used in regions of excessive rainfall or precipitation if it is possible to secure creosote.

The Committee calls attention to the line showing the division between the use of creosote and zinc chloride treatment for cross-ties in Bulletin No. 213 of January, 1919, page 150, where it was recommended that the territory north and west of the black line should be considered zinc chloride territory, and that south and east should be considered creosote territory.

In December, 1919, Bulletin No. 222, page 338, a revision of this map was published again showing "Proposed line showing the division between the use of creosote and zinc treatment for cross ties." On this map it was indicated that creosote oil should be used east of the revision line and zinc chloride west of the revision line.

Now that conditions have become more or less normal, it would appear desirable to more accurately define regions in which zinc chloride can economically be used for the treatment of cross ties. The reason for the drawing of the original map limiting the use of creosote and leaving the larger territory of the United States for use of zinc chloride was a specific war emergency due to the fact that only a very small amount of creosote was available. In other words, it was practically a line limiting the use of creosote. At the present time a line for limiting the use of creosote for tie treatment is evidently no longer necessary, because it is generally accepted that when it can be economically used creosote may be employed in any section of the United States.

A line, furthermore, does not correctly delineate regions where zinc chloride should be used. The choice between the two preservatives is after all one depending upon the risk taken in making an initial investment, meaning thereby the probable life which can be estimated for ties with either treatment. It is generally agreed that zinc chloride will give the best results in regions in which excessive rainfall is absent.

If any delineation is made it should be in terms of areas in the United States instead of whole regions as in the map published in 1919. This map is wrong, both for creosote and for zinc, and the recommendation is that it be withdrawn and a map prepared, if this can be done, showing in forms of shaded areas, regions where reasonable returns may be expected from ties treated with zinc chloride. Such shaded areas should, if possible, indicate in terms of length of life what may be reasonably expected from zinc treated ties laid in that territory.

The Committee was unable to complete such a map this year and suggests that this be made a subject for next year.

Recommendations:

The Committee recommends the use of zinc chloride as an economical investment.

Test Sections:

REASON FOR TEST SECTIONS:

(1) Life records—This will give a stimulus to longer life, of *all* ties and a general interest in the tie performance on the railroad.

(2) On the assumption that the test sections are representative of average conditions on the railroad, they indicate the tie performance on the divisions.

HOW TO MAKE A TEST SECTION:

(1) Select a section representative of average conditions on the Division. This section should be selected by the Division Staff.

(2) Test sections should be a Section Foreman's section.

(3) The general practice of the railroad in renewing ties should be followed as distinguished from the practice of renewing ties out of face.

(4) The ties when inserted should be marked with dating nails. The psychological effect on the Foreman by the use of dating nails on treated ties is usually underestimated. A dating nail in a cross tie means to the Foreman that the tie in question is expected to give longer service than the tie not so marked, and he will do his utmost to conserve that tie. It also serves as his record of the life of all treated ties in his particular track and he will exert himself to the utmost to prolong the life of such treated ties, especially when he knows that the dating nails are a record and he will be checked up on the service life given by the ties on his section as compared with ties on adjacent sections.

Record of Test Section:

(1) One person should be responsible for all test sections (the necessary assistance to be employed to secure the proper record).

(2) This record should be kept by individual ties in each section in a book provided for that purpose.

(3) Annual inspection should be made and a report prepared of the results obtained to the end of the year, copy of this report to go to all Officials interested and the Section Foreman in charge of test sections.

(4) All ties removed should be held until inspected by the Official in charge of the test section.

(5) Section Foremen should prepare a report each month of ties inserted and removed. This should include kind of wood treatment, date inserted, and reason for removal. This report should go to the Official in charge of test sections.

The Committee recommends that test sections be established, and when established, the method to be followed be in accordance with recommendations herein.

Dating of All Ties:

It is the recommendation of the Committee that all ties inserted in the track should be marked with a dating nail, indicating the year in which they were inserted. This is the only means available for identifying the ties and determining just what service life is secured. This recommendation not concurred in by one member of the Sub-Committee.

The effect on the Foreman and the tendency to watch a dated tie with more care than an undated tie, is clearly brought out in paragraph (4) under heading of "How to Make a Test Section."

Extend test records to include treated timbers in bridges, docks and wharves:

Your Committee prepared a questionnaire to cover the practices in use of treated timbers in bridges, docks and wharves, which was forwarded to various railroads.

To date we have received replies from fifty-six railroads, thirty-one of which indicate that treated material is used to a considerable extent in bridges, docks and wharves, and its use is being extended each year. Some of the railroads were confining the use of treated material to piling, stringers and caps of their open deck trestles and to timbers in the floor system of ballasted deck bridges. Twenty-five of these railroads answered to the effect they had no experience as yet with treated timbers in such structures.

All railroads that have used treated timbers in their bridges, docks and wharves to any extent, speak very highly of the benefits they are receiving from such use.

On account of the meager information that was secured, it is not possible to prepare a report at this time that will show anything but progress. It is, therefore, suggested that the various railroads be requested to keep a record of the treated timbers in their bridges, docks and wharves, as is done in connection with their treated ties. If this record is started and continued it will furnish valuable information which will emphasize the importance and economy in the use of treated timber in these structures.

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
C. B. & Q..........	Lines West.....	Ash.........	....	....	....	Creosote.....	Full cell.....
C. B. & Q..........	Lines West.....	Ash.........	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Ash.........	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West.....	Ash.........	....	....	....	None........	Untreated...
P. R. R............	Western Divn..	Beech.......	....	....	....	Creosote.....	....
Ill. Cent............	Greenville, Miss.........	Beech.......	....	....	....	J. M. Long's liquid.....	....
C. B. & Q..........	Lines West.....	Beech.......	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Beech.......	....	....	....	None........	Untreated...
G. C. & S. F.......	Beaumont, Tex.	Beech.......	....	Sawed...	....	None........	Untreated...
P. R. R............	Western Divn..	Beech.......	....	....	....	Zinc chloride	Burnett......
P. R. R............	Western Divn..	Beech.......	....	....	....	Zinc chloride	Burnett......
G. C. & S. F.......	Beaumont, Tex.	Beech.......	....	Sawed...	....	Zinc chloride	Burnett......
G. C. & S. F.......	Beaumont, Tex.	Beech.......	....	....	....	Zinc creosote	Allardyce....
G. C. & S. F.......	Beaumont, Tex.	Beech.......	....	Sawed...	....	Zinc creosote	....
G. C. & S. F.......	Beaumont, Tex.	Beech.......	....	Hewed..	....	Zinc tannin..	Wellhouse...
C. B. & Q..........	Lines West.....	Birch, red...	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Birch, red...	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West.....	Birch, red...	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Birch, red...	....	....	....	None........	Untreated...
C. & N. W..........	Elmhurst, Ill..	Cedar.......	....	....	....	None........	Untreated...
C. R. I. & P........	Vinton, Iowa..	Cedar.......	6"x8"x8'	Hewed..	Seasoned	None........	Untreated...
C. B. & Q..........	Lines West.....	Cottonwood.	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Cottonwood.	....	....	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Hewed..	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Hewed..	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Hewed..	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Hewed..	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Sawed...	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Sawed...	....	None........	Untreated...
G. H. & S. A.......	Watkins Cut-Off.....	Cypress.....	....	Sawed...	....	None........	Untreated...
C. B. & Q..........	Lines West....	Elm, white..	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Elm, white..	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Elm, white..	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Elm, white..	....	....	....	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Green...	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Green...	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...

*Followed by heavy creosote treatment. **Figures indicate tons per year.

SERVICE TESTS OF TIES **Exhibit A**

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition					Date 100% Removed	Aver. Life, Years
			Tie Plates		Kind of Spikes	Ballast	Traffic**		
			Kind	Size					
9.62	1	1909	Yes		Cut	Clay and cinders		1918	9.0
	30	1909	Yes		Cut	Cinders, gravel, rock, clay		1915	4.8
	56	1909	Yes		Cut	Cinders, gravel, clay		1916	4.7
	15	1910	Yes		Cut	Stone		1918	7.1
	16	1905						1915	9.8
	48	1910	Economy			Dirt		1916	4.3
	15	1910	Yes		Cut	Cinders, gravel, clay		1919	7.1
	109	1909	Yes		Cut	Cinders, gravel, clay		1920	4.3
	100	1902	None		Cut	Sand	Heavy	1906	3.0
	13835	1902						1917	8.9
	9937	1901						1916	11.1
	99	1902	None		Cut	Sand	Heavy	1914	10.5
0.24 zinc, 3.0 creo.	50	1902	None		Cut	Sand	Heavy	1914	8.9
0.3 zinc*	50	1902	None		Cut	Sand	Heavy	1908	5.0
0.87 zinc	100	1902	None		Cut	Sand	Heavy	1914	10.5
	48	1909	Yes		Cut	Cinders, gravel, clay		1914	3.9
	89	1909	Partly		Cut	Cinders, gravel, clay		1914	3.1
	30	1910	Yes		Cut	Stone		1915	3.4
	49	1910	Yes		Cut	Gravel		1918	4.5
	1000	1903	50% Wolhaupter, 50% without	4x6		Stone		1918	13.3
	2001	1898		5x7½	Cut	Gravel	4,745,000 tons per year	1917	17.2
	30	1909	Yes		Cut	Cinders, gravel, clay		1914	3.5
	56	1909	Partly		Cut	Cinders, gravel, clay		1915	3.1
	282	1895	Yes			Dirt		1918	17.3
	568	1895	None			Dirt		1918	17.3
	44	1895	Yes			Rock		1914	17.6
	73	1895	None			Earth		1918	17.6
	654	1895	None			Earth		1916	14.9
	374	1895	Yes			Earth		1916	14.9
	641	1895	Yes			Rock		1914	14.9
	48	1909	Yes		Cut	Cinders, gravel, clay		1916	5.0
	88	1909	Partly		Cut	Cinders, gravel, clay		1920	5.6
	30	1908	On curves		Cut	Gravel		1914	5.0
	25	1910	Yes		Cut	Gravel		1920	5.4
	264	1906	Sellers		Cut	Gravel	Heavy	1917	8.1
	350	1906	Sellers		Cut	Gravel	Heavy	1917	8.3
	100	1906	Sellers		Screw and cut	Gravel	Heavy	1917	8.3
	100	1906	Sellers		Screw and cut	Gravel	Heavy	1917	8.3

Records of Completed

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Green...	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Green...	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Green...	None........	Untreated...
Northern Pacific...	Maywood, Wash........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Seasoned	None........	Untreated...
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett......
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett......
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Southern Pacific....	Various........	Douglas Fir (coast)....	7"x9"x8'	Sawed...	Partly seasoned	Zinc chloride	Burnett.....
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition					Date 100% Re-moved	Aver. Life, Years
			Tie Plates		Kind of Spikes	Ballast	Traffic		
			Kind	Size					
....	58	1906	None............	......	Screw.........	Gravel..........	Heavy........	1917	7.7
....	96	1906	Sellers	......	Screw.........	Gravel..........	Heavy........	1917	8.4
....	47	1906	Sellers...........	......	Cut and screw.	Gravel..........	Heavy........	1917	8.1
....	91	1906	Sellers...........	......	Cut and screw.	Gravel..........	Heavy........	1917	8.8
....	46	1906	Sellers...........	......	Screw.........	Gravel..........	Heavy........	1917	7.8
....	99	1906	None............	......	Cut...........	Gravel..........	Heavy........	1917	7.8
....	100	1906	None............	......	Cut...........	Gravel..........	Heavy........	1916	7.3
....	284	1906	Sellers...........	......	Cut	Gravel..........	Heavy........	1917	8.4
0.243	217	1895	Servis and Wolhaupter....	......	Cut...........	Stone, gravel and earth..........	Heavy........	1908	11.3
0.243	4043	1896	Servis and Wolhaupter....	......	....	Stone, gravel and earth..........	Heavy........	1909	10.9
0.243	1941	1897	Servis and Wolhaupter....	......	....	Stone, gravel and earth..........	Heavy........	1910	10.7
0.243	20536	1898	Servis and Wolhaupter ...	......	....	Stone, gravel and earth..........	Heavy........	1912	10.9
0.243	12951	1899	Servis and Wolhaupter....	......	....	Stone, gravel and earth..........	Heavy........	1913	10.5
0.243	26146	1900	Servis and Wolhaupter....	......	....	Stone, gravel and earth..........	Heavy........	1913	9.2
0.243	43681	1901	Servis and Wolhaupter....	......	....	Stone, gravel and earth..........	Heavy........	1916	10.4
0.243	58983	1905	Servis and Wolhaupter....	......	....	Stone, gravel and earth..........	Heavy........	1916	10.2
0.243	48478	1906	Servis and Wolhaupter....	......	Cut...........	Stone, gravel and earth..........	Heavy........	1917	9.7
0.243	44689	1908	Servis and Wolhaupter....	......	Cut...........	Stone, gravel and earth..........	Heavy........	1917	7.2
....	95	1907	Sellers and Wolhaupter....	......	Screw and cut.	Gravel..........	Heavy........	1916	7.6
....	94	1907	Wolhaupter.......	......	Cut...........	Gravel..........	Heavy........	1915	7.6
....	108	1907	Sellers...........	......	Screw and cut.	Gravel..........	Heavy........	1916	7.8
....	91	1907	Sellers...........	......	Cut...........	Gravel..........	Heavy........	1915	7.6
....	90	1907	Sellers...........	......	Screw.........	Gravel..........	Heavy........	1915	7.7
....	92	1907	Sellers...........	......	Cut...........	Gravel..........	Heavy........	1916	7.6
....	32	1907	Wolhaupter.......	......	Screw and cut.	Gravel..........	Heavy........	1916	7.6
....	90	1907	Wolhaupter.......	......	Cut...........	Gravel..........	Heavy........	1916	7.6

Records of Completed

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Douglas Fir (mountain)	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Hewed..	Seasoned before and after treating..	....	Vulcanized...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Sawed...	Seasoned before and after treating..	....	Vulcanized...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Hewed..	Seasoned before and after treating..	....	Vulcanized...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Sawed...	Seasoned before and after treating..	....	Vulcanized...
G. C. & S. F.......	Beaumont, Tex.	Gum........	....	....	....	Zinc chloride	Burnett......
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Sawed...	Seasoned before and after treating..	Zinc tannin..	Wellhouse...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Hewed..	Seasoned before and after treating..	Zinc tannin..	Wellhouse...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Hewed..	Seasoned before and after treating..	Zinc tannin..	Wellhouse...
Norfolk Southern...	Norfolk, Va., Division.....	Gum........	....	Sawed...	Seasoned before and after treating..	Zinc tannin..	Wellhouse...
C. B. & Q.........	Lines West....	Gum, red....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Gum, red....	....	....	....	None........	Untreated...
C. B. & Q.........	Chicago, Ill....	Gum, red....	....	....	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	....	....	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6"x8"x8'	Sawed...	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	....	....	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6"x8"x8'	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6"x8"x8'	Sawed...	....	Zinc chloride	Burnett......

SERVICE TESTS OF TIES—Continued

Exhibit A—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Tie Plates: Size	Kind of Spikes	Ballast	Traffic	Date 100% Removed	Aver. Life, Years
...	90	1907	Sellers...	...	Cut...	Gravel...	Heavy...	1916	7.6
...	90	1907	Sellers...	...	Cut...	Gravel...	Heavy...	1916	7.6
...	90	1907	Sellers...	...	Screw and cut.	Gravel...	Heavy...	1916	7.7
...	90	1907	Sellers...	...	Screw and cut.	Gravel...	8,270,506 tons..	1916	7.7
...	89	1907	N. P...	...	Cut...	Gravel...	Heavy...	1916	7.6
...	25	1897	Servis...	...	...	...	...	1905	2.9
...	25	1897	Servis...	...	...	...	...	1909	6.7
...	100	1897	...	...	...	...	...	1905	2.8
...	100	1897	...	...	...	...	...	1906	4.5
...	3	1902	None...	...	Cut...	Sand...	Heavy...	1914	10.0
1.36	100	1897	Servis...	...	...	...	...	1918	14.3
4.2	100	1897	Servis...	...	...	...	...	1918	16 3
...	25	1897	Servis...	...	...	...	...	1918	16.0
...	25	1897	Servis...	...	...	...	...	1914	11.2
...	53	1909	Yes...	...	Cut...	Cinders, gravel, clay...	...	1919	4.6
...	98	1909	Partly...	...	Cut...	Cinders, gravel, clay...	...	1918	3.7
...	31	1908	On curves...	...	Cut...	Gravel...	...	1911	3.0
...	16	1905	Glendon...	...	...	...	...	1908	2.4
...	11	1905	...	...	Screw...	...	...	1908	2.6
...	14	1905	None...	...	...	...	...	1908	3.0
0.30	49	1905	None...	...	...	...	...	1917	8.9
0.30	34	1905	Glendon...	...	...	...	...	1917	7.3

Records of Completed

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	Seasoned 1 year after treatment....	Zinc creosote	Allardyce....
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	Seasoned 1 year after treatment....	Zinc creosote	Allardyce....
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, red....	6″x8″x8′	Sawed...	Seasoned 1 year after treatment....	Zinc creosote	Allardyce....
St. L.-S. F.	Pacific, Mo....	Gum, red....	....	....	....	Zinc creosote	Giussani.....
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo.	6″x8″x8′	Sawed...	Seasoned 1 year after treatment....	Creosote.....	Full cell.....
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	Seasoned 1 year after treatment....	Creosote.....	Full cell.....
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	Seasoned 1 year after treatment....	Creosote.....	Full cell.....
C. B. & Q...........	Lines West.....	Gum, tupelo	....	....	....	None........	Untreated...
C. B. & Q...........	Lines East.....	Gum, tupelo	....	....	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	None........	Untreated...
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc chloride	Burnett......
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc creosote	Allardyce....

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Size	Kind of Spikes	Ballast	Traffic	Date 100% Removed	Aver. Life, Years
0.30	32	1905			Screw			1917	9.3
0.27	44	1905	None					1917	8.8
0.27	45	1905	Glendon					1916	7.0
0.27	40	1905			Screw			1917	9.3
0.27 zinc, 4.49 creo.	16	1905	Glendon					1918	10.4
0.27 zinc, 4.49 creo.	12	1905			Screw			1918	11.7
0.27 zinc, 4.49 creo.	17	1905	None					1918	10.4
	18	1905						1919	13.0
13.2	23	1905			Screw			1918	13.6
13.2	30	1905	Glendon					1918	12.0
13.2	35	1905	None					1918	10.9
	48	1909	Yes		Cut	Cinders, gravel, clay		1915	3.9
	88	1909	Partly		Cut	Cinders, gravel, clay		1916	2.9
	14	1905	None					1910	2.3
	15	1905	Glendon					1910	2.6
	13	1905			Screw			1910	2.6
0.234	30	1905	None					1917	8.0
0.234	33	1905	Glendon					1917	7.9
0.224	46	1905	None					1917	7.0
0.224	37	1905	Glendon					1917	7.0
0.224	30	1905			Screw			1917	7.0
0.234	22	1905			Screw			1914	7.2
0.22 zinc, 2.02 creo.	12	1905			Screw			1918	7.4

Records of Completed

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc creosote	Allardyce....
G. H. & S. A.......	Bayview and San Leon, Tex.	Gum, tupelo	6″x8″x8′	Sawed...	....	Zinc creosote	Allardyce....
N. Y. N. H. & H..	Medway, Mass.	Hemlock....	6″x8″x8′	Hewed..	....	Creosote.....	....
C. B. & Q..........	Lines West.....	Hemlock....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Hemlock....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Hemlock....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West.....	Hemlock....	....	....	....	None........	Untreated...
G. C. & S. F.......	Beaumont, Tex.	Hemlock....	....	Hewed..	....	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
C. & N. W..........	Janesville, Wis.	Hemlock....	6″x8″x8′	Hewed..	Seasoned	None........	Untreated...
P. R. R............	Western Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Chicago Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Western Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Chicago Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Western Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Chicago Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Chicago Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Western Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Western Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
P. R. R............	Western Divn..	Hemlock....	....	....	....	Zinc chloride	Burnett.....
G. C. & S. F.......	Beaumont, Tex.	Hemlock....	....	....	....	Zinc creosote	....
G. C. & S. F.......	Beaumont, Tex.	Hemlock....	....	Hewed..	....	Zinc creosote	Allardyce....
G. C. & S. F.......	Beaumont, Tex.	Hemlock....	....	Hewed..	....	Zinc tannin..	Wellhouse...
P. R. R............	Hanna.........	Hemlock....	....	....	....	Zinc tannin..	Wellhouse...
C. & N. W..........	Belle-Plaine and Miami...	Hemlock....	....	Hewed..	....	Zinc tannin..	Wellhouse...
Northern Pacific....	Maywood, Wash.........	Hemlock....	7″x9″x8′	Hewed..	Green...	None........	Untreated...
Northern Pacific....	Maywood, Wash.........	Hemlock....	7″x9″x8′	Sawed...	Green...	None........	Untreated...
C. B. & Q..........	Lines West.....	Hickory, Pignut.....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West.....	Hickory, Pignut.....	....	....	....	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	Creosote....	Full cell.....
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	Creosote....	Full cell.....
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...

*Followed by heavy creosote treatment.

Service Tests of Ties—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Tie Plates: Size	Kind of Spikes	Ballast	Traffic	Date 100% Removed	Aver. Life, Years
0.22 zinc, 2.02 creo.	14	1905	Glendon					1918	10.0
0.22 zinc, 2.02 creo.	16	1905	None					1918	8.5
	400	1880			Cut	Gravel		1912	20.0
	30	1910	Yes		Cut	Stone		1918	5.4
	25	1910	Yes		Cut	Gravel		1918	6.4
	88	1909	Partly		Cut	Cinders, gravel, clay		1916	4.2
	48	1909	Yes		Cut	Cinders, gravel, clay		1918	5.2
	101	1902	None		Cut	Sand	Heavy	1904	2.0
	20	1907	None		Cut	Gravel	Light	1916	5.9
	20	1907	None		Cut	Gravel	Light	1915	7.0
	20	1907	None		Cut	Gravel	Light	1915	6.3
	20	1907	None		Cut	Gravel	Light	1915	6.9
	20	1907	None		Cut	Gravel	Light	1915	6.2
	20	1907	None		Cut	Gravel	Light	1916	5.6
	49	1907	None		Cut	Gravel	Light	1919	7.3
	200	1892						1907	10.9
	698	1896						1908	11.4
	5909	1897						1916	10.2
	4786	1897						1911	10.1
	438	1898						1915	9.7
	275	1898						1910	8.3
	1000	1899						1913	11.6
	1048	1899						1916	9.7
	521	1900						1915	8.9
	713	1898						1915	9.2
0.3 zinc*	49	1902	None		Cut	Sand	Heavy	1914	5.0
0.24 zinc, 3.0 creo.	50	1902	None		Cut	Sand	Heavy	1911	9.0
0.54	100	1902						1914	11.1
	200	1892						1905	10.7
	11990	1905 and 1906	Wolhaupter					1913	12.0
	100	1906	Sellers		Cut	Gravel	Heavy	1915	7.3
	103	1906	None		Cut	Gravel	Heavy	1915	7.3
	30	1909	Yes		Cut	Cinders, gravel, clay		1918	4.9
	15	1910	Yes		Cut	Stone		1919	6.5
8.0	25	1897	50% tie plated					1918	15.4
8.0	75	1897	50% tie plated					1918	20.2
	50	1897						1908	8.4
	100	1897						1917	15.2
	200	1897						1917	12.5
	100	1897			Goldie			1917	13.7
	120	1897						1918	13.4
	100	1897						1918	13.6

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Norfolk Southern...	Norfolk, Va., Division.....	Juniper......	....	Hewed..	Seasoned	None........	Untreated...
Northern Pacific....	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Seasoned	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Green...	None........	Untreated...
Northern Pacific...	Plains, Mont...	Larch,western	7"x9"x8'	Hewed..	Green...	None........	Untreated...
C. B. & Q..........	Lines West....	Maple, hard.	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Maple, hard.	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Maple, hard.	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West....	Maple, hard.	....	....	....	None........	Untreated...
C. & N. W.........	Calamus, Iowa	Maple, hard.	6"x7"x8'	Hewed..	Green...	None........	Untreated...
C. B. & Q..........	Lines East.....	Maple, soft..	....	....	....	None........	Untreated...
C. B. & Q..........	Lines East.....	Maple, soft..	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West....	Maple, soft..	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West....	Maple, soft..	....	....	....	None........	Untreated...
G. C. & S. F.......	Beaumont,Tex.	Oak, black..	6"x8"x8'	....	....	Barschall salts.......	Hasselmann.
G. C. & S. F.......	Beaumont,Tex.	Oak, black..	6"x8"x8'	....	....	None........	Untreated...
G. C. & S. F.......	Beaumont,Tex.	Oak, black..	6"x8"x8'	....	....	Zinc chloride	Burnett.....
G. C. & S. F.......	Beaumont,Tex.	Oak, black..	6"x8"x8'	....	Steamed	Zinc creosote	....
G. C. & S. F.......	Beaumont,Tex.	Oak, black..	6"x8"x8'	....	Steamed	Zinc creosote	Allardyce....
G. C. & S. F.......	Beaumont,Tex.	Oak, black..	6"x8"x8'	....	....	Zinc tannin..	Wellhouse...
B. & O.............	Medora, Ind...	Oak,chestnut	....	....	Seasoned	None........	Untreated...
C. B. & Q..........	Lines West....	Oak, pin.....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West....	Oak, pin.....	....	....	....	None........	Untreated...
P. R. R............	Philadelphia and Chester.	Oak, pin.....	....	....	....	Wood tar creosote...	....
G. C. & S. F.......	Beaumont,Tex.	Oak, red.....	6"x8"x8'	....	....	Barschall salts.......	Hasselmann.
Illinois Central.....	Greenville, Miss.........	Oak, red....	....	....	....	Cresol-calcium....	....
P. R. R............	Western Divn..	Oak, red....	....	....	....	Creosote.....	Rueping.....
Illinois Central.....	Greenville, Miss.........	Oak, red....	....	....	Seasoned	J. N. Long's liquid.....	....
St. L.-S. F.........	Pacific, Mo....	Oak, red....	....	....	....	Not known..	....
C. B. & Q..........	Lines West....	Oak, red....	....	....	....	None........	Untreated...
C. B. & Q..........	Lines West....	Oak, red....	....	....	....	None........	Untreated...

Service Tests of Ties—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Size	Kind of Spikes	Ballast	Traffic	Date 100% Removed	Aver. Life, Years
	100	1897	Lugs and dips					1918	13.6
	100	1897	Felt					1918	13.1
	100	1897						1918	13.8
	125	1897	Servis					1914	11.3
	27	1907	Wooden and Wolhaupter		Screw and cut	Gravel	Heavy	1915	6.9
	90	1907	Wolhaupter		Cut	Gravel	Heavy	1915	7.2
	90	1907	Sellers		Cut	Gravel	Heavy	1915	7.6
	90	1907	Sellers		Cut	Gravel	Heavy	1915	7.3
	90	1907	Sellers		Screw and cut	Gravel	Heavy	1916	7.4
	90	1907	Sellers		Screw	Gravel	Heavy	1916	7.8
	91	1907	N. P		Cut	Gravel	Heavy	1915	7.3
	92	1907	Sellers		Screw	Gravel	Heavy	1916	7.8
	91	1907	Sellers		Screw and cut	Gravel	Heavy	1915	7.4
	91	1907	Sellers		Cut	Gravel	Heavy	1915	7.4
	90	1907	Sellers		Cut	Gravel	Heavy	1915	7.5
	91	1907	Wolhaupter		Cut	Gravel	Heavy	1915	7.2
	96	1907	Wooden and Wolhaupter		Screw and cut	Gravel	Heavy	1915	6.9
	30	1909	Yes		Cut	Cinders, gravel, clay		1916	4.7
	52	1909	Partly		Cut	Cinders, gravel, clay		1915	3.8
	23	1910	Yes		Cut	Gravel		1920	4.3
	15	1910	Yes		Cut	Stone		1918	6.1
	100	1914	None		Cut	Stone		1919	
	25	1910	Yes		Cut	Gravel		1920	3.4
	57	1909	Partly		Cut	Cinders, gravel, clay		1920	4.4
	14	1910	Yes		Cut	Stone		1914	3.9
	29	1909	Yes		Cut	Cinders, gravel, clay		1909	4.2
	118	1902	None		Cut	Sand	Heavy	1908	3.8
	24	1902	None		Cut	Sand	Heavy	1908	4.0
0.35	34	1902	None		Cut	Sand	Heavy	1911	8.0
	76	1902	None		Cut	Sand	Heavy	1904	1.8
0.24 zinc, 3.0 creo.	60	1902	None		Cut	Sand	Heavy	1914	8.2
0.33 zinc.	33	1902	None		Cut	Sand	Heavy	1914	8.0
	424	1904						1916	7.7
	15	1910	Yes		Cut	Stone		1920	6.7
	30	1909	Yes		Cut	Cinders, gravel, clay		1920	5.6
	18	1902						1914	5.0
	19	1902	None		Cut	Sand	Heavy	1908	3.9
	9	1910						1916	4.0
	9	1905						1915	10.0
0.135	50	1910	Economy, 50% tie plated			Dirt		1916	4.7
	4	1905						1914	9.0
	60	1909	Yes		Cut	Cinders, gravel, clay		1915	5.0
	15	1910	Yes		Cut	Stone		1920	7.1

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
C. B. & Q.	Lines East	Oak, red				None	Untreated
C. B. & Q.	Lines East	Oak, red				None	Untreated
G. C. & S. F.	Beaumont, Tex.	Oak, red				None	Untreated
P. R. R.	Scio, Ohio	Oak, red				None	Untreated
P. R. R.	Harrisburg and Williamsport	Oak, red				Wood tar creosote	
P. R. R.	Baltimore, Md.	Oak, red				Wood tar creosote	
P. R. R.	Baltimore, Md.	Oak, red				Wood tar creosote	
P. R. R.	Baltimore, Md.	Oak, red				Wood tar creosote	
P. R. R.	Camden, N. J.	Oak, red				Wood tar creosote	
P. R. R.	New York and Philadelphia	Oak, red				Wood tar creosote	Dipped
P. R. R.	Camden, N. J.	Oak, red				Wood tar creosote	Dipped
P. R. R.	New York and Philadelphia	Oak, red				Wood tar creosote	Dipped
P. R. R.	Camden, N. J.	Oak, red				Wood tar creosote	Dipped
P. R. R.	Camden, N. J.	Oak, red				Wood tar creosote	Dipped
G. C. & S. F.	Beaumont, Tex.	Oak, red	6"x8"x8'	Hewed	Seasoned and steamed	Zinc chloride	Burnett
N. & S.	Norfolk, Va.	Oak, red		Sawed	Seasoned	Zinc chloride	Burnett
P. R. R.	Pittsburgh, Pa.	Oak, red				Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Oak, red				Zinc chloride	Boiled
G. H. & S. A.	Louisiana	Oak, red	7"x8"x8'	Hewed	Seasoned	Zinc creosote	Low pressure
G. C. & S. F.	Beaumont, Tex.	Oak, red	6"x8"x8'	Hewed	Seasoned and steamed	Zinc tannin	Wellhouse
G. C. & S. F.	Beaumont, Tex.	Oak, Spanish	6"x8"x8'			Barschall salts	Hasselmann.
G. C. & S. F.	Beaumont, Tex.	Oak, Spanish	6"x8"x8'			None	Untreated
G. C. & S. F.	Beaumont, Tex.	Oak, turkey		Hewed		Barschall salts	Hasselmann.
G. C. & S. F.	Beaumont, Tex.	Oak, turkey		Hewed		None	Untreated
G. C. & S. F.	Beaumont, Tex.	Oak, turkey	6"x8"x8'		Seasoned and steamed	Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Oak, turkey				Zinc creosote	Allardyce
G. C. & S. F.	Beaumont, Tex.	Oak, turkey	6"x8"x8'			Zinc creosote	Allardyce
G. C. & S. F.	Beaumont, Tex.	Oak, turkey	6"x8"x8'	Hewed	Seasoned and steamed	Zinc tannin	Wellhouse
G. C. & S. F.	Beaumont, Tex.	Oak, water				Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Oak, white	6"x8"x8'			Barschall salts	Hasselmann.
G. C. & S. F.	Beaumont, Tex.	Oak, white	6"x8"x8'			None	Untreated
Illinois Central	Memphis, Tenn.	Oak, white				None	Untreated
T. C. I. & R. Co.	Ensley, Ala.	Oak, white	8"x7"x9'	Sawed	Seasoned	None	Untreated
B. & O.	Washington Terminal	Oak, white	7"x7"x8'-6"	Hewed		None	Untreated
N. & S.	Norfolk, Va.	Oak, white		Hewed	Seasoned	None	Untreated
P. S. & N.	New York	Oak, white	6"x8"x8'-6"	Sawed		None	Untreated

*Followed by heavy creosote treatment.

SERVICE TESTS OF TIES—Continued

Exhibit A—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Track Condition: Tie Plates: Size	Track Condition: Kind of Spikes	Track Condition: Ballast	Track Condition: Traffic	Date 100% Re-moved	Aver. Life, Years
....	25	1910	Yes...........	......	Cut..........	Gravel.........	....	1919	6.0
....	50	1908	On curves.......	......	Cut..........	....	....	1920	6.5
....	93	1902	None...........	......	Cut..........	Sand...........	Heavy........	1911	3.0
....	1900	1907	Flat bottom.....	6x9	Cut..........	Stone..........	....	1916	5.7
....	250	1895	....	......	....	....	....	1914	7.0
....	16	1896	....	......	....	....	....	1914	4.0
....	27	1896	....	......	....	....	....	1914	6.8
....	55	1896	....	......	....	....	....	1914	5.3
....	180	1895	....	......	....	....	....	1914	4.0
....	250	1895	....	......	....	....	....	1914	5.7
....	297	1896	....	......	....	....	....	1914	5.3
....	250	1895	....	......	....	....	....	1914	4.5
....	591	1896	....	......	....	....	....	1914	5.5
....	2910	1896	....	......	....	....	....	1914	6.4
0.35	20	1902	None...........	......	Cut..........	Sand...........	Heavy........	1909	7.0
....	25	1897	Servis..........	......	....	....	....	1907	5.5
....	135	1897	....	......	....	....	....	1916	10.7
....	3	1902	None...........	......	Cut..........	Sand...........	Heavy........	1914	7.0
....	250	1906	I. & W.........	......	Cut..........	Gravel.........	....	1917	10.5
0.33 zinc...	20	1902	None...........	......	Cut..........	Sand...........	Heavy........	1909	7.0
....	20	1902	None...........	......	Cut..........	Sand...........	Heavy........	1908	4.0
....	20	1902	None...........	......	Cut..........	Sand...........	Heavy........	1908	4.0
....	19	1902	None...........	......	Cut..........	Sand...........	Heavy........	1906	3.0
....	20	1902	None...........	......	Cut..........	Sand...........	Heavy........	1909	4.3
0.35	19	1902	None...........	......	Cut..........	Sand...........	Heavy........	1909	7.0
0.24 zinc, 3.0 creo.	10	1902	None...........	......	Cut..........	Sand...........	Heavy........	1905	4.5
0.3 zinc*...	10	1902	None...........	......	Cut..........	Sand...........	Heavy........	1914	3.0
0.33 zinc...	20	1902	None...........	......	Cut..........	Sand...........	Heavy........	1914	7.5
....	2	1902	None...........	......	Cut..........	Sand...........	Heavy........	1914	12.0
....	196	1902	None...........	......	Cut..........	Sand...........	Heavy........	1914	6.5
....	196	1902	None...........	......	Cut..........	Sand...........	Heavy........	1914	8.8
....	8400	1901	....	......	....	....	....	1909	4.5
....	34	1910	Goldie..........	......	Cut..........	Sand and dirt....	....	1919	7.0
....	137000	1904	Flat bottom.....	......	Cut..........	Stone and cinders	1,460,000 tons..	1918	8.3
....	300	1897	....	......	....	....	....	1910	8.6
....	65725	1902	Wolhaupter......	6x8½	Cut..........	Slag...........	4,000,000 tons..	1920	12.9

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
P. R. R.	New York and Philadelphia	Oak, white				Wood tar creosote	
P. R. R.	Camden and Trenton	Oak, white				Wood tar creosote	Brush
P. R. R.	Baltimore, Md.	Oak, white				Wood tar creosote	Brush
P. R. R.	Baltimore, Md.	Oak, white				Wood tar creosote	Brush
P. R. R.	Baltimore, Md.	Oak, white				Wood tar creosote	Brush
P. R. R.	Baltimore, Md.	Oak, white				Wood tar creosote	Brush
P. R. R.	Baltimore, Md.	Oak, white				Wood tar creosote	Brush
P. R. R.	Baltimore, Md.	Oak, white				Wood tar creosote	Brush
P. R. R.	New York and Philadelphia	Oak, white				Wood tar creosote	Dipped
P. R. R.	Altoona, Pa.	Oak, white				Wood tar creosote	Dipped
P. R. R.	New York and Philadelphia	Oak, white				Wood tar creosote	Dipped
P. R. R.	New York and Philadelphia	Oak, white				Wood tar creosote	Dipped
P. R. R.	Camden and Trenton	Oak, white				Wood tar creosote	Dipped
P. R. R.	Camden and Trenton	Oak, white				Wood tar creosote	Dipped
G. C. & S. F.	Beaumont, Tex.	Oak, white	6"x8"x8'		Seasoned and steamed	Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Oak, white	6"x8"x8'		Seasoned and steamed	Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Oak, white	6"x8"x8'		Steamed	Zinc creosote	
G. C. & S. F.	Beaumont, Tex.	Oak, willow				Barschall salts	Hasselmann
G. C. & S. F.	Beaumont, Tex.	Oak, willow				None	Untreated
G. C. & S. F.	Beaumont, Tex.	Oak, willow				Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Oak, willow			Seasoned and steamed	Zinc creosote	Allardyce
G. C. & S. F.	Beaumont, Tex.	Oak, willow				Zinc creosote	Allardyce
G. C. & S. F.	Beaumont, Tex.	Oak, willow				Zinc tannin	Wellhouse
A. T. & S. F.	La Junta, Colo.	Pine, Colo.				Zinc tannin	Wellhouse
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Barschall salts	Hasselmann
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Beaumont oil	
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Beaumont oil and zinc chloride	
P. R. R.	Wooster, Ohio.	Pine, loblolly	7"x8"x8½'	Sawed and hewed	Seasoned	Creosote	Full cell

*Followed by heavy creosote treatment.

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition					Date 100% Removed	Aver. Life, Years
			Tie Plates		Kind of Spikes	Ballast	Traffic		
			Kind	Size					
...	104	1892	...	...	...	...	...	1914	7.0
...	551	1894	...	...	...	...	...	1914	5.8
...	204	1897	...	...	...	...	...	1914	9.0
...	386	1897	...	...	...	...	...	1914	8.0
...	597	1897-8	...	...	...	...	...	1914	9.0
...	72	1898	...	...	...	...	...	1914	9.0
...	541	1897	...	...	...	...	...	1914	9.5
...	232	1898	...	...	...	...	...	1914	10.0
...	475	1897	...	...	...	...	...	1914	4.0
...	2	1894	...	...	...	...	...	1914	15.0
...	70	1895	...	...	...	...	...	1914	5.5
...	348	1896	...	...	...	...	...	1914	4.0
...	600	1896	...	...	...	...	...	1914	5.5
...	86	1897	...	...	...	...	...	1914	5.0
0.26	100	1902	None...	...	Cut...	Sand...	Heavy...	1914	10.5
0.35	100	1902	None...	...	Cut...	Sand...	Heavy...	1909	6.8
0.3 zinc*...	107	1902	None...	...	Cut...	Sand...	Heavy...	1905	2.2
...	20	1902	None...	...	Cut...	Sand...	Heavy...	1906	3.2
...	20	1902	None...	...	Cut...	Sand...	Heavy...	1906	3.2
0.35	20	1902	None...	...	Cut...	Sand...	Heavy...	1909	7.0
0.24 zinc, 3.0 creo..	10	1902	None...	...	Cut...	Sand...	Heavy...	1911	8.0
0.3 zinc....	11	1902	None...	...	Cut...	Sand...	Heavy...	1905	3.0
0.33 zinc...	20	1902	None...	...	Cut...	Sand...	Heavy...	1911	7.0
...	50	1882	...	...	...	...	...	1897	11.8
...	99	1902	None...	...	Cut...	Sand...	Heavy...	1906	3.5
...	42	1902	None...	...	Cut...	Sand...	Heavy...	1911	3.8
0.25	80	1902	None...	...	Cut...	Sand...	Heavy...	1911	9.0
8-10	2743	1910	Flat bottom...	7x9 to 7x13½	Cut and screw.	Stone...	20,000,000 tons.	1918	6.4

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
Illinois Central	Greenville, Miss.	Pine, loblolly			Seasoned	J. M. Long's liquid	
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly			Seasoned	Spirittine	
C. B. & Q.	Lines West	Pine, loblolly				None	Untreated
C. B. & Q.	Lines West	Pine, loblolly				None	Untreated
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				None	Untreated
C. & N. W.	Calamus, Iowa	Pine, loblolly	6"x7"x8'	Hewed	Green	None	Untreated
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Zinc creosote	Allardyce
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Zinc creosote	
G. C. & S. F.	Beaumont, Tex.	Pine, loblolly				Zinc tannin	Wellhouse
Union Pacific	Wyoming	Pine, lodgepole				Zinc chloride	Burnett
Union Pacific	Kansas	Pine, lodgepole	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Kansas	Pine, lodgepole	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Colorado	Pine, lodgepole	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Nebraska	Pine, lodgepole	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Nebraska	Pine, lodgepole	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf	6"x8"x8'			Barschall salts	Hasselmann
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf		Hewed		Beaumont oil	
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf				Beaumont oil and zinc chloride	
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf				Spirittine	
A. C. L.	Waycross, Ga.	Pine, longleaf	7"x9"x8½'	Hewed	Seasoned	None	Untreated
C. M. & St. P.	Rio, Wis.	Pine, longleaf	6"x8"x8'	Sawed		None	Untreated
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf	6"x8"x8'			None	Untreated
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, longleaf	7"x9"x8'	Sawed		None	Untreated
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, longleaf	7"x9"x8'	Sawed		None	Untreated
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, longleaf	7"x9"x8'	Sawed		None	Untreated
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, longleaf	7"x9"x8'	Sawed		None	Untreated
G. H. & S. A.	Watkins Cut-Off, Tex.	Pine, longleaf				None	Untreated
G. H. & S. A.	Watkins Cut-Off, Tex.	Pine, longleaf				None	Untreated
G. H. & S. A.	Watkins Cut-Off, Tex.	Pine, longleaf				None	Untreated
C. & N. W.	Calamus, Iowa	Pine, longleaf	6"x7"x8'	Hewed	Green	None	Untreated
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf				Zinc chloride	Boiled
N. Y. N. H. & H.	Rowayton, Conn.	Pine, longleaf	8"x10"-8'4"	Sawed		Zinc chloride	Burnett
N. Y. N. H. & H.	Rowayton, Conn.	Pine, longleaf	8"x10"-8'4"	Sawed		Zinc chloride	Burnett
N. Y. N. H. & H.	Rowayton, Conn.	Pine, longleaf	8"x10"-8'4"	Sawed		Zinc chloride	Burnett
N. Y. N. H. & H.	Rowayton, Conn.	Pine, longleaf	8"x10"-8'4"	Sawed		Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Pine, longleaf	6"x8"x8'		Steamed	Zinc creosote	
P. R. R.	Philadelphia and Chester	Pine, miscl.				Wood tar creosote	

*Followed by heavy creosote treatment.

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition					Date 100% Removed	Aver. Life, Years
			Tie Plates		Kind of Spikes	Ballast	Traffic		
			Kind	Size					
0.826	174	1910	Economy 50% tie plated			Dirt		1916	5.5
3.3	100	1902	None		Cut	Sand	Heavy	1911	3.6
	30	1910	Yes		Cut	Stone		1920	5.1
	61	1909	Yes		Cut	Cinders, gravel, clay		1920	5.2
	100	1902	None		Cut	Sand	Heavy	1904	2.0
	100	1914	Sellers		Cut	Gravel		1920	6.0
0.35	100	1902	None		Cut	Sand	Heavy	1911	9.0
0.24 zinc, 3.0 creo.	49	1902	None		Cut	Sand	Heavy	1911	9.0
0.3 zinc*	49	1902	None		Cut	Sand	Heavy	1911	9.0
0.33 zinc	99	1902	None		Cut	Sand	Heavy	1914	8.0
	242000	1886						1897	9.0
0.40	46	1903	No. 18	8½x8	Cut	Cinders	1,747,988 tons	1919	16.0
0.40	26	1904	No. 18	8½x8	Cut	Cinders	1,747,988 tons	1919	15.0
0.40	31	1905	No. 37	8¾x8	Cut	Gravel	5,110,999 tons	1919	14.8
	9	1909	No. 37		Cut	Gravel	9,339,940 tons	1918	9.0
0.40	33	1904	No. 37	8¾x8	Cut	Gravel	11,017,435 tons	1919	14.4
	100	1902	None		Cut	Sand	Heavy	1914	6.0
3.00	100	1902	None		Cut	Sand	Heavy	1911	5.0
	100	1902	None		Cut	Sand	Heavy	1914	4.0
3.3	100	1902	None		Cut	Sand	Heavy	1914	10.0
	50	1915	Flange		Cut	Gravel		1920	4.0
	2100	1899	None		Cut	Gravel	Heavy	1917	12.1
	93	1902	None		Cut	Sand	Heavy	1911	3.5
	434	1905	None					1917	4.7
	382	1905	Glendon					1914	4.1
	184	1905			Screw			1916	4.0
	4	1905			Screw			1911	5.5
	158	1895	Yes			Rock		1914	9.0
	717	1895	Yes			Earth		1914	9.0
	769	1895				Earth		1914	9.0
	100	1914	Sellers		Cut	Stone		1920	6.0
	6	1902	None		Cut	Sand	Heavy	1914	12.0
	57	1901	Yes	5x8	Cut	Stone		1914	13.0
	68	1901	Yes	5x8	Cut	Stone		1916	14.4
	67	1901	Yes	5x8	Cut	Stone		1916	14.8
	14	1901	Yes	5x8	Cut	Stone		1914	12.8
	50	1902	None		Cut	Sand		1914	9.7
	18	1902						1914	5.0

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
P. R. R.	Williamsport, Pa.	Pine, miscl.				Wood tar creosote	
D. & I. M.		Pine, miscl.			Seasoned	Zinc tannin	Wellhouse
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, sap	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, sap	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
G. H. & S. A.	Bayview and San Leon, Tex.	Pine, sap	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
G. H. & S. A.	Galveston, Tex.	Pine, sap	7"x8"x8'	Hewed		Zinc creosote	Allardyce
G. H. & S. A.	Galveston, Tex.	Pine, sap	7"x8"x8'	Hewed		Zinc creosote	Allardyce
G. H. & S. A.	Galveston, Tex.	Pine, sap	7"x8"x8'	Hewed		Zinc creosote	Allardyce
G. C. & S. F.	Beaumont, Tex.	Pine, shortleaf		Sawed		Barschall salts	Hasselmann.
G. C. & S. F.	Beaumont, Tex.	Pine, shortleaf		Sawed		None	Untreated
G. C. & S. F.	Beaumont, Tex.	Pine, shortleaf				Zinc chloride	Boiled
G. C. & S. F.	Beaumont, Tex.	Pine, shortleaf				Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Pine, shortleaf		Sawed		Zinc chloride	Burnett
Southern Pacific	Glidden Dist.	Pine, shortleaf			Green	Zinc chloride	Burnett
Southern Pacific	San Antonio District	Pine, shortleaf			Green	Zinc chloride	Burnett
Southern Pacific	Del Rio District	Pine, shortleaf			Green	Zinc chloride	Burnett
Southern Pacific	Sanderson District	Pine, shortleaf			Green	Zinc chloride	Burnett
Southern Pacific	Vallentine District	Pine, shortleaf			Green	Zinc chloride	Burnett
Southern Pacific	El Paso District	Pine, shortleaf			Green	Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Pine, southern yellow				Avenarius carbolineum	
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Hewed	Seasoned		Vulcanized
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Hewed	Seasoned		Vulcanized
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Sawed	Seasoned		Vulcanized
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Sawed	Seasoned		Vulcanized
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Sawed	Seasoned		Vulcanized
G. C. & S. F.	Beaumont, Tex.	Pine, southern yellow				Diamond wood preservative	
G. H. & S. A.	Lafayette and Scott, La.	Pine, southern yellow			Seasoned	None	Untreated
G. H. & S. A.	Lafayette and Scott, La.	Pine, southern yellow			Seasoned	None	Untreated
P. R. R.	Altoona, Pa.	Pine, southern yellow				Creosote and rosin	Creo-resinate

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Track Condition: Tie Plates: Size	Track Condition: Kind of Spikes	Track Condition: Ballast	Track Condition: Traffic	Date 100% Removed	Aver. Life, Years
	1	1889						1914	8.0
	86	1890			Cut	Gravel	Light	1908	15.0
0.4122	334	1905			Screw			1914	5.4
0.4122	334	1905	None					1916	5.5
0.4122	333	1905	Glendon					1917	5.6
0.27 zinc, 4.49 creo.	127	1905	None					1918	8.3
0.27 zinc, 4.49 creo.	126	1905	Glendon		Screw			1918	10.4
0.27 zinc, 4.49 creo.	750	1905						1917	11.1
	98	1902	None		Cut	Sand	Heavy	1914	4.9
	100	1902	None		Cut	Sand	Heavy	1906	3.4
	4	1902	None		Cut	Sand	Heavy	1914	10.0
	3	1902	None		Cut	Sand	Heavy	1914	10.6
	100	1902	None		Cut	Sand	Heavy	1914	10.0
0.55	6048	1885-1891				Gravel		1898	6.8
0.55	41691	1885-1891				Gravel		1898	8.2
0.55	15564	1885-1891				Gravel		1898	8.9
0.55	2607	1885-1891						1898	6.7
0.55	12899	1885-1891				Fine gravel		1898	7.0
0.55	13397	1885-1891						1898	7.5
	84	1905	None		Cut	Sand	Heavy	1914	5.0
	100	1897						1899	2.0
	25	1897	None					1900	2.3
	100	1897						1908	4.3
	46	1897						1900	3.0
	25	1897	Servis					1908	3.5
	19	1902	None		Cut	Sand	Heavy	1908	2.9
	75	1907	Wolhaupter		Cut	Gravel		1914	2.7
	25	1907	Servis		Cut	Gravel		1914	2.7
	500	1901						1914	9.0

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
P. R. R.	Pittsburgh, Pa.	Pine, southern yellow				Creosote and rosin	Creo-resinate
P. R. R.	Seaside, N. J.	Pine, southern yellow				Creosote and rosin	Creo-resinate
P. R. R.	Seaside, N. J.	Pine, southern yellow				Creosote and rosin	Creo-resinate
P. R. R.	Jamesburg, N.J.	Pine, southern yellow				Creosote and rosin	Creo-resinate
N. Y. N. H. & H.	Fair Haven, Conn.	Pine, southern yellow	7"x9"x8'	Hewed		Creosote	
N. Y. N. H. & H.	Fair Haven, Conn.	Pine, southern yellow	7"x9"x8'	Hewed		Creosote	Full cell
A. T. & S. F.	Sutton, Kan.	Pine, southern yellow		Hewed		Creosote	Rueping
A. T. & S. F.	Newton, Kan.	Pine, southern yellow		Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Norfolk, Neb.	Pine, southern yellow	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Norfolk, Neb.	Pine, southern yellow	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
Union Pacific	Norfolk, Neb.	Pine, southern yellow	7"x9"x8'	Hewed	Seasoned	Zinc chloride	Burnett
G. H. & S. A.	Watkins Cut-Off	Pine, southern yellow		Hewed		Zinc creosote	Allardyce
G. H. & S. A.	Watkins Cut-Off	Pine, southern yellow				Zinc creosote	Allardyce
G. H. & S. A.	Watkins Cut-Off	Pine, southern yellow		Hewed		Zinc creosote	Allardyce
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Hewed	Seasoned	Zinc tannin	Wellhouse
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Sawed	Seasoned	Zinc tannin	Wellhouse
Norfolk & Southern	Norfolk, Va.	Pine, southern yellow		Hewed	Seasoned	Zinc tannin	Wellhouse
Great Northern	Moravia, Idaho	Pine, western yellow	Triangular, 12" face, 1" edge	Sawed	Seasoned	Zinc chloride	Burnett
D. & I.	Minnesota	Pine, white			Seasoned	Zinc tannin	Wellhouse
C. B. & Q.	Lines West	Poplar				None	Untreated
C. B. & Q.	Lines West	Poplar				None	Untreated
P. R. R.	Philadelphia and Chester	Poplar				Wood tar creosote	
G. C. & S. F.	Beaumont, Tex.	Redwood, Calif.				Zinc chloride and Calif. oil	
G. C. & S. F.	Beaumont, Tex.	Redwood, Calif.				Zinc chloride	Burnett
C. B. & Q.	Lines West	Sycamore				None	Untreated
C. B. & Q.	Lines East	Sycamore				None	Untreated
C. B. & Q.	Lines East	Sycamore				None	Untreated
G. C. & S. F.	Beaumont, Tex.	Tamarack	6"x8"x8'			Barschall salts	Hasselmann.

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Track Condition: Tie Plates: Size	Track Condition: Kind of Spikes	Track Condition: Ballast	Track Condition: Traffic	Date 100% Removed	Aver. Life, Years
	250	1901						1914	7.5
	125	1901						1914	9.0
	125	1901						1914	10.0
	125	1901						1914	10.0
	200	1907			Cut	Stone		1918	11.0
	500	1906			Cut	Stone		1918	12.0
4.56	44	1905	Yes	6x8 and 7½x9	Cut	Clay		1920	13.8
0.58	6357	1904	Yes	7½x9	Cut	Rock	15,034,755 tons.	1920	12.8
0.40	5	1911	No. 18	8½x8	Cut			1919	8.0
0.40	36	1909	No. 18	8½x8	Cut			1919	10.0
0.40	81	1908	No. 18	8½x8	Cut			1919	11.0
0.6	189	1895	None			Rock		1914	14.0
0.6	1095	1895	None			Earth		1917	15.6
0.6	410	1895	Yes			Rock		1914	14.0
	100	1897						1918	16.5
	100	1897						1918	15.8
	25	1897	Servis					1918	16.0
0.5	2916	1903	Goldie	6x8½	Cut	Gravel	6,052,224 tons	1917	13.2
	85	1890			Cut	Gravel	Light	1908	15.0
	15	1910	Yes		Cut	Stone		1919	5.5
	30	1909	Yes		Cut	Cinders, clay, gravel		1920	5.2
	17	1902			Cut			1914	5.0
	8	1902	None		Cut	Sand	Heavy	1905	2.0
0.35	2	1902	None		Cut	Sand	Heavy	1905	2.0
	15	1910	Yes		Cut	Stone		1915	4.0
	55	1909	Partly		Cut	Cinders, gravel, clay		1918	2.7
	25	1910	Yes		Cut	Gravel		1915	3.4
	98	1902	None		Cut	Sand	Heavy	1911	4.0

RECORDS OF COMPLETED

Railroad	Location	Species	Dimensions	Form	Preparation	Preservative	Process
C. & N. W.	Janesville, Wis.	Tamarack	...	Hewed	Seasoned	None	Untreated
C. & N. W.	Janesville, Wis.	Tamarack	...	Hewed	Seasoned	None	Untreated
C. & N. W.	Janesville, Wis.	Tamarack	...	Hewed	Seasoned	None	Untreated
C. & N. W.	Janesville, Wis.	Tamarack	...	...	...	None	Untreated
C. B. & Q.	Lines East	Tamarack	...	...	...	None	Untreated
C. B. & Q.	Lines East	Tamarack	...	...	...	None	Untreated
C. B. & Q.	Lines West	Tamarack	...	...	...	None	Untreated
G. C. & S. F.	Beaumont, Tex.	Tamarack	...	...	...	None	Untreated
Great Northern	Fortine, Mont.	Tamarack	7"x8"x8'	Sawed and hewed	...*	None	Untreated
Great Northern	Rimrock, Mont.	Tamarack	7"x9"x8'	Sawed and hewed.	Seasoned	None	Untreated
Great Northern	Newport, Wash.	Tamarack	7"x9"x8'	Sawed and hewed.	Green	None	Untreated
C. & N. W.	Verdi, Minn.	Tamarack	6"x7"x8'	Hewed	Green	None	Untreated
C. & N. W.	Chadron, Neb.	Tamarack	6"x7"x8'	Hewed	Green	None	Untreated
G. C. & S. F.	Beaumont, Tex.	Tamarack	...	...	...	Zinc chloride	Burnett
G. C. & S. F.	Beaumont, Tex.	Tamarack	6"x8"x8'	...	Seasoned steamed	Zinc creosote	...
G. C. & S. F.	Beaumont, Tex.	Tamarack	...	...	Seasoned steamed	Zinc creosote	Allardyce
D. & I.	Minnesota	Tamarack	...	...	Seasoned and steamed	Zinc tannin	Wellhouse
G. C. & S. F.	Beaumont, Tex.	Tamarack	...	...	Seasoned and steamed	Zinc tannin	Wellhouse
P. R. R.	Kosciusko, Ill.	Tamarack	...	...	...	Zinc tannin	Wellhouse

*Followed by heavy creosote treatment.

Appendix C

(3) DOUGLAS FIR .

R. S. BELCHER, *Chairman;* W. E. BURKHALTER, ANDREW GIBSON, J. F. PINSON, B. H. PRATER, J. H. WATERMAN, *Sub-Committee*

Your Sub-Committee was requested to make final report, if practicable, on the preservative treatment of Douglas Fir. Our report will be confined to the treatment of Douglas Fir ties, for the reason that the treatment of fir lumber and fir piling are large subjects of themselves, and we would recommend that a Sub-Committee on fir treatment be appointed next year and a special study made of the treatment of fir lumber and piling as now practiced, and recommendations made as to standard practice.

SERVICE TESTS OF TIES—Continued **Exhibit A**—Continued

Absorption Lbs. Per Cubic Foot	No. Ties	Date Set	Track Condition: Tie Plates: Kind	Tie Plates: Size	Kind of Spikes	Ballast	Traffic	Date 100% Removed	Aver. Life, Years
....	125	1907	None............	......	Cut...........	Gravel..........	Light.........	1917	6.4
....	62	1907	None............	......	Cut...........	Gravel..........	Light.........	1916	6.2
....	25	1907	None............	......	Cut...........	Gravel..........	Light.........	1915	6.5
....	20	1907	....	......	Cut...........	Gravel..........	Light.........	1918	6.6
....	88	1909	Partly...........	......	Cut...........	Cinders, gravel, clay..........	....	1915	4.7
....	10	1910	Yes.............	......	Cut...........	Gravel..........	....	1919	6.3
....	47	1909	Yes.............	......	Cut...........	Cinders, gravel, clay..........	....	1916	4.9
....	49	1902	None............	......	Cut...........	Sand............	....	1905	3.0
....	2168	1904	None............	......	Cut...........	Gravel..........	....	1914	7.4
....	2916	1908	N. P. No. 58....	6x8½	Cut..........	Gravel..........	2,146,500 tons..	1918	7.6
....	2894	1908	N. P. No. 21....	6x8½	Cut..........	Gravel..........	6,052,224 tons..	1918	6.7
....	100	1914	None............	......	Cut..........	Gravel..........	....	1920	6.0
....	100	1914	Sellers..........	......	Cut..........	Gravel..........	....	1920	6.0
0.41	49	1902	None............	......	Cut..........	Sand............	Heavy........	1914	10.0
0.3 zinc*...	51	1902	None............	......	Cut..........	Sand............	Heavy........	1914	8.0
0.24 zinc, 3.0 creo..	50	1902	None............	......	Cut..........	Sand............	Heavy........	1911	9.0
....	85	1890	....	......	Cut..........	Gravel..........	Light.........	1908	15.0
0.58	100	1902	None............	......	Cut..........	Sand............	Heavy........	1912	10.0
....	200	1892	....	......	....	Gravel..........	....	1905	8.8

General Requirements for Douglas Fir Tie Treatment

Your Sub-Committee believes that the preparation of Douglas Fir for treatment is well covered in the Manual under "Specifications for Preservative Treatments—General Requirements."

Perforating or Incising

The outstanding development in the preparation of Douglas Fir ties for treatment is called perforating, or incising. In fact such an improvement in the distribution of the preservative does such preparation effect that your Sub-Committee recommends very strongly that all Douglas Fir ties be perforated before treatment.

The Douglas Fir log having such a small percentage of sapwood, sawn Douglas Fir ties are practically all heartwood. While the heartwood is extremely resistant to the penetration of the preservative perpendicular to the fibre, yet the preservative penetrates the heartwood readily parallel to the fibre from any point where the fibre has been cut.

Perforation of the ties not only aids the preservative to effect an entrance into the wood, and enables a more uniform penetration of preservative to be obtained, but also reduces materially the period of time necessary to season fir ties for treatment, and reduces surface checking of the ties to a great extent.

The Perforating Machine

There are only two perforating machines in this country, to the knowledge of your Sub-Committee. One of them, owned by the St. Helens Creosoting Company, St. Helens, Oregon, is briefly described as follows:

The cut on the following page shows the machine photographed from different angles. The picture in the lower left-hand corner shows the outgoing side of the machine and the vertical perforating cylinders, also the tension springs which supply sufficient pressure so that the entire length of the tooth which protrudes from the cylinder, enters the wood. The machine has two vertical and two horizontal perforating cylinders and four surfaces of the ties are perforated at one time. Nine eight-foot ties per minute may be perforated when fed into the machine as fast as it will handle them. A fifteen horse power motor drives the machine and is mounted on frame of the machine as shown in upper right-hand picture.

The Perforations

The cut on the next page shows the shape of the perforations at the surface of the tie, and their arrangement. A cut of one of the teeth is also shown.

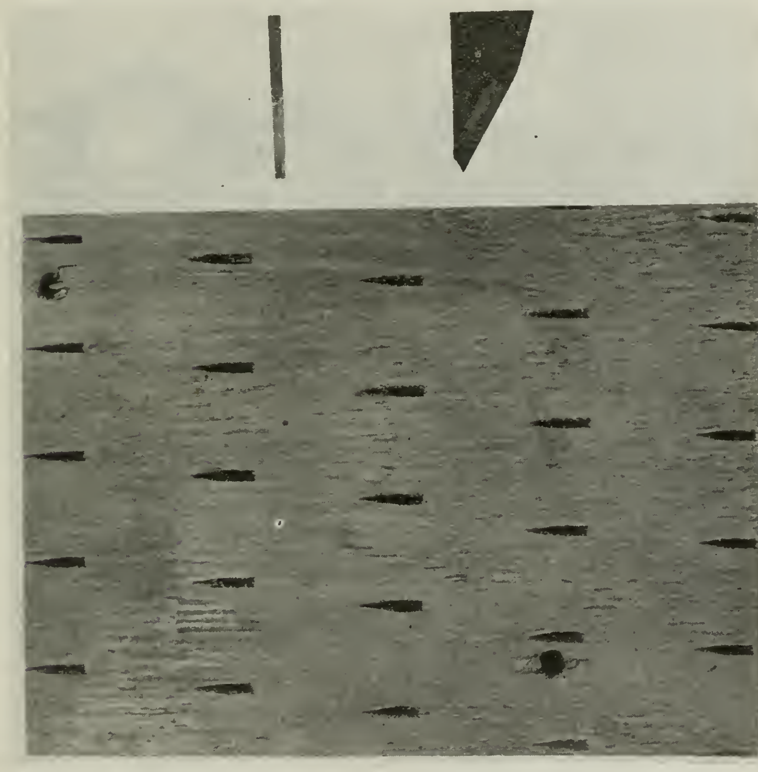
The tooth enters the surface of the tie at an angle of approximately 60 degrees to the surface of the tie. As the perforating cylinder revolves the tooth is forced into the wood, the tooth becoming perpendicular, of course, when its entire length has penetrated the wood, and the sharp edge of the tooth parting the fibres as the tooth is again forced to an angle in leaving the wood.

The perforations shown in the illustration are two inches apart lengthwise of the tie, one and one-quarter inches across the tie and offset one-quarter inch. The tooth is one-eighth inch thick. This arrangement requires that the preservative penetrate five inches each way from the perforation with the fibre, but only requires one-sixteenth inch penetration across the fibre to make impregnation of surface of the tie complete to the depth of the perforations, which are three-quarters of an inch in depth.

As development of perforation of Douglas Fir ties goes on it is probable that the spacing of the perforations will be improved, and it is probable, also, that the shape of the teeth will be improved. It is recommended that Sub-Committee on this subject next year continue the study of the spacing and type of tooth with a view to improvement of both.

Treatment of Douglas Fir Ties With Zinc Chloride

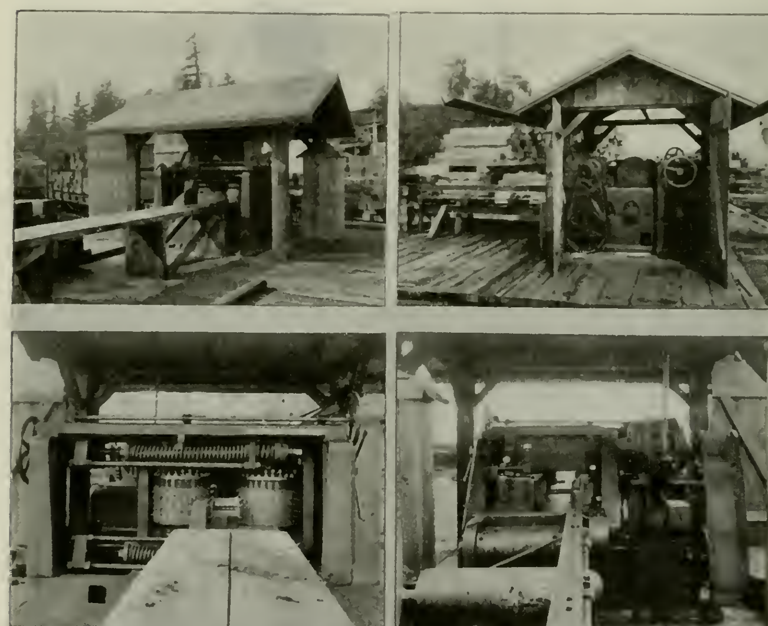
Your Sub-Committee recommends that the treatment for Douglas Fir ties with Zinc Chloride be in accordance with the specification for the "Preservative Treatment of Wood with Zinc Chloride" as already approved by this Association.



PERFORATIONS

Exoerimental Treatments of Douglas Fir Ties With Zinc Chloride

Your Sub-Committee has carried on some experimental treatments on thoroughly seasoned Douglas Fir ties, both perforated and non-perforated. This work was done in a small experimental treating cylinder in which ten ties are treated at one time. A summary of results of these experimental treatments is attached hereto. In this summary the treatment given each group of runs is indicated and under this is given the average absorption in volume per cent for each run, also the average. absorption in volume per cent for the group. It will be noted that the perforated ties, given the same treatment as the non-perforated, in general, show a much higher absorption in volume per cent. This is due to perforations permitting solution to penetrate the sides of the ties as shown in the following illustration of un-perforated and perforated ties.



PHOTOGRAPHS SHOWING VIEWS OF PERFORATING MACH NE ST HELENS, OREGON

In these photographs the potassium ferrocyanide uranium acetate visual test has been applied, the dark portions indicate that portion of the wood to which the zinc chloride solution has not penetrated. The immense improvement in the treatment of Douglas Fir due to perforations may be seen by referring to the following photographs.

It appears from our experimental treatments that seasoned perforated fir ties were treated to refusal when the pressure, gradually increased to 175 pounds in 1 hour and 30 minutes, had been held 4 hours, and non-perforated ties, when the pressure, increased to 175 pounds, in 1 hour and 30 minutes, had been held 5 hours.

Douglas Fir, Burnett—Chloride Zinc

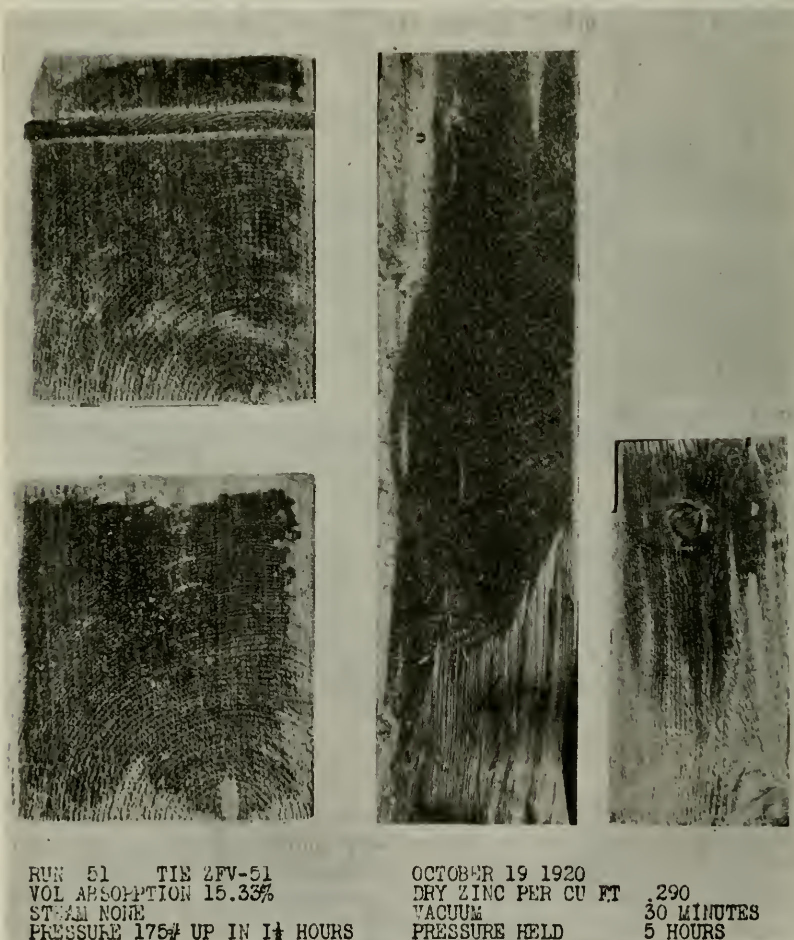
Summary of Treatment

(Treatments Shown in Columns Is Treatment Given Groups Shown Below)

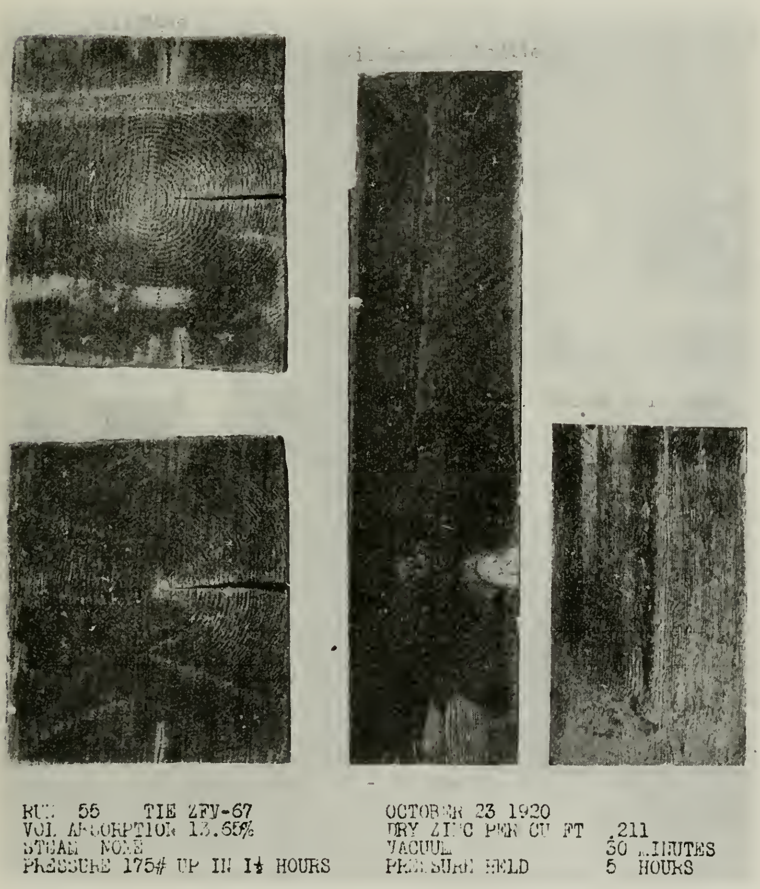
	Thirty Minutes' Pressure					Two Hours' Pressure			Three Hours' Pressure				Four Hours' Pressure		Five Hours' Pressure			Ten Hours' Press're
	Group No. 1	Group No. 2	Group No. 5	Group No. 4	Group No. 5	Group No. 6	Group No. 7	Group No. 8	Group No. 9	Group No. 10	Group No. 11	Group No. 12	Group No. 13	Group No. 14	Group No. 15	Group No. 16	Group No. 17	Group No. 18
Steam, 20 Lbs......	None	1′ 00″	2′ 00″	4′ 00″	6′ 00″	None	2′ 00″	5′ 00″	None	2′ 00″	3′ 00″	4′ 00″	None	2′ 00″	None	5′ 00″	2′ 00″	None
Blow-Off.........	None	30″	30″	30″	30″	None	30″	10″	None	30″	30″	30″	None	30″	None	30″	30″	None
Initial Vacuum.....	30″	30″	30″	30″	30″	30″	30″	1′ 00″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″
Solution:																		
Introducing.......	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″	10″
Press. 175 lbs. up in	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″	1′ 30″
Pressure Held....	30″	30″	30″	30″	30″	2′ 00″	2′ 00″	2′ 00″	3′ 00″	3′ 00″	3′ 00″	3′ 00″	4′ 00″	4′ 00″	5′ 00″	5′ 00″	5′ 00″	10′ 00″
Forcing Back.....	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″	30″
Total Time.........	3′ 10″	4′ 40″	5′ 40″	7′ 40″	9′ 40″	4′ 40″	7′ 10″	10′ 10″	5′ 40″	8′ 10″	9′ 10″	10′ 10″	6′ 40″	9′ 10″	7′ 40″	13′ 10″	10′ 10″	12′ 40″
ABSORPTION VOLUME PER CENT NON-PERFORATED TIES																		
1st Run............	23.28	24.23	20.95	25.24	24.87	28.73	22.49	25.82	26.35	23.33	27.46	27.14	24.87	26.67	37.99	30.05	32.11	27.30
2nd Run............	....	18.99	22.28	23.86	21.85	31.59	23.23	....	19.21	....	28.46	....	....	....	34.50	28.31	....	34.39
3rd Run............	....	18.89	....	....	....	26.03	24.97	....	....	....	....	....	....	....	....	....	....	....
4th Run............	....	24.39	....	....	....	23.49	24.97	....	....	....	....	....	....	....	....	....	....	....
5th Run............	....	21.75	....	....	....	23.86	26.56	....	....	....	....	....	....	....	....	....	....	....
General Average....	23.28	21.65	21.61	24.55	23.36	26.74	24.44	25.82	22.78	23.33	27.96	27.14	24.87	62.67	36.25	29.18	32.11	30.85
ABSORPTION VOLUME PER CENT PERFORATED TIES—1¼ INCHES, CENTER TO CENTER																		
1st Run............	....	....	....	....	....	....	....	....	35.02	31.95	....	....	35.24	43.48	40.10	....	32.54	....
2nd Run............	....	....	....	....	....	....	....	....	30.25	34.65	....	....	40.20	32.21	42.32	....	36.56	....
3rd Run............	....	....	....	....	....	....	....	....	34.76	29.68	....	....	38.93	40.52	30.73	....	39.04	....
4th Run............	....	....	....	....	....	....	....	....	33.33	31.05	....	....	36.77	34.06	38.51	....	36.72	....
5th Run............	....	....	....	....	....	....	....	....	....	....	....	....	....	....	37.25	....	....	....
General Average....	....	....	....	....	....	....	....	....	33.34	31.83	....	....	37.78	37.57	37.78	....	36.21	....

NOTE—Ties in Group No. 8 received 30 Lbs. Steam instead of 20 Lbs.

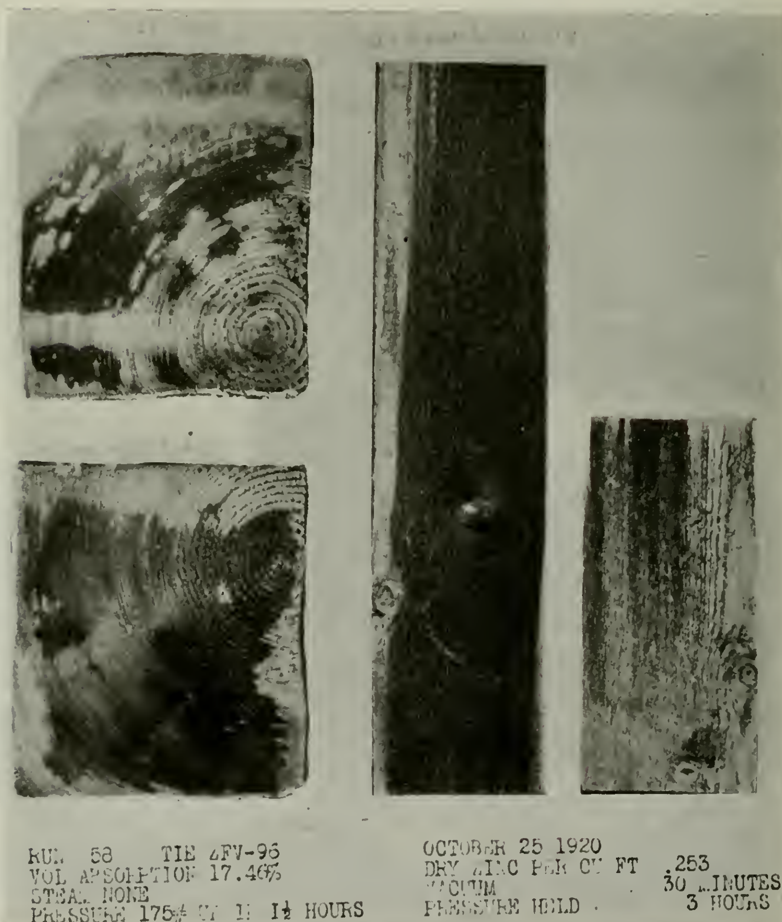
Office Manager Treating Plants, Topeka, Kan., September 30, 1921.



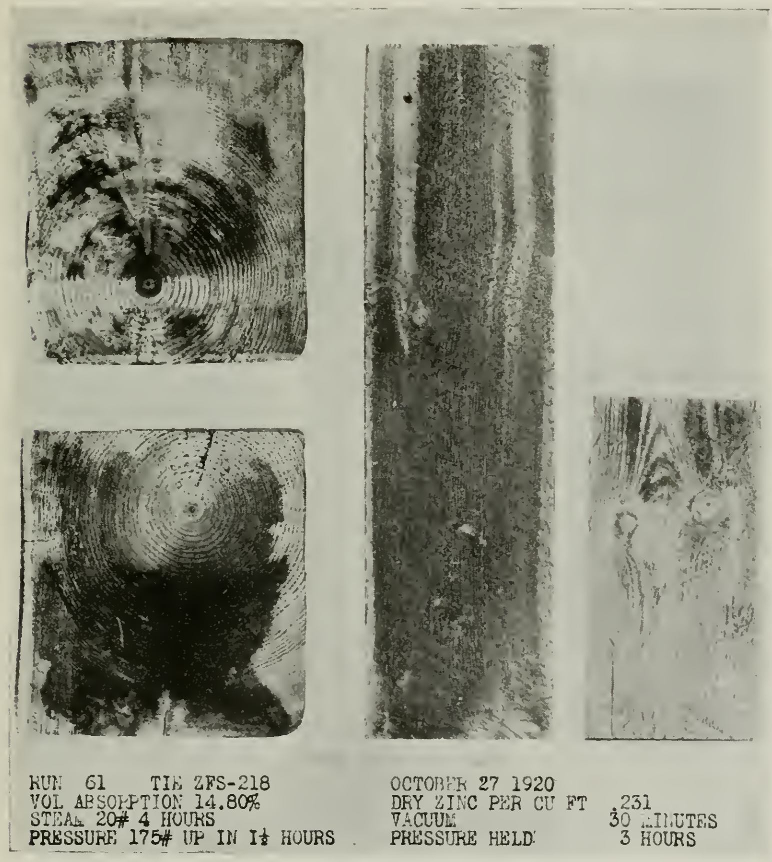
SAWN DOUGLAS FIR TIE—UNPERFORATED



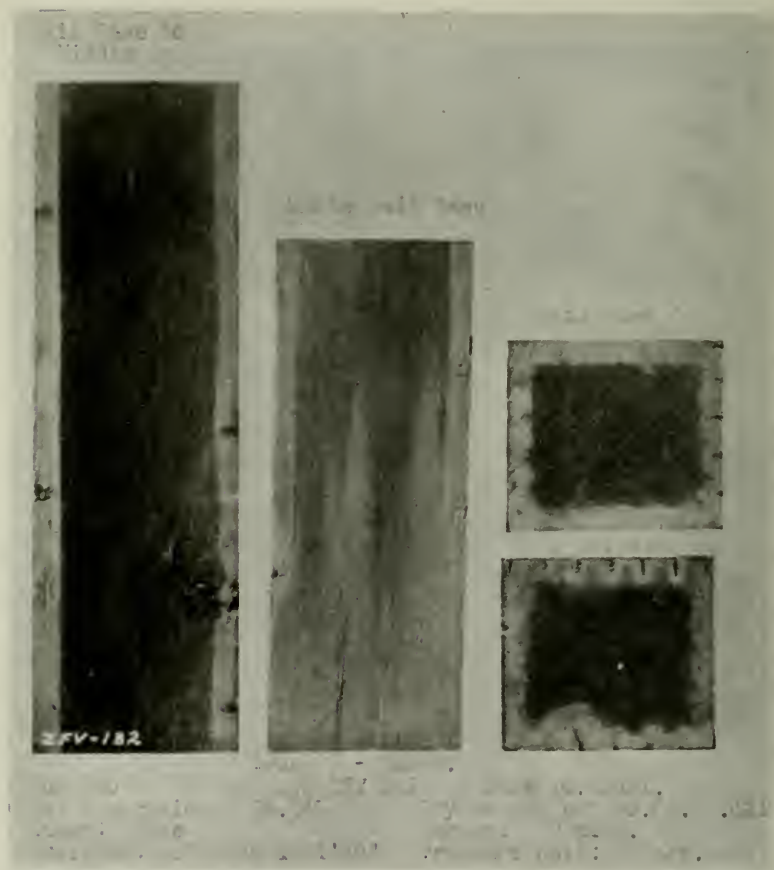
SAWN DOUGLAS FIR TIE—UNPERFORATED



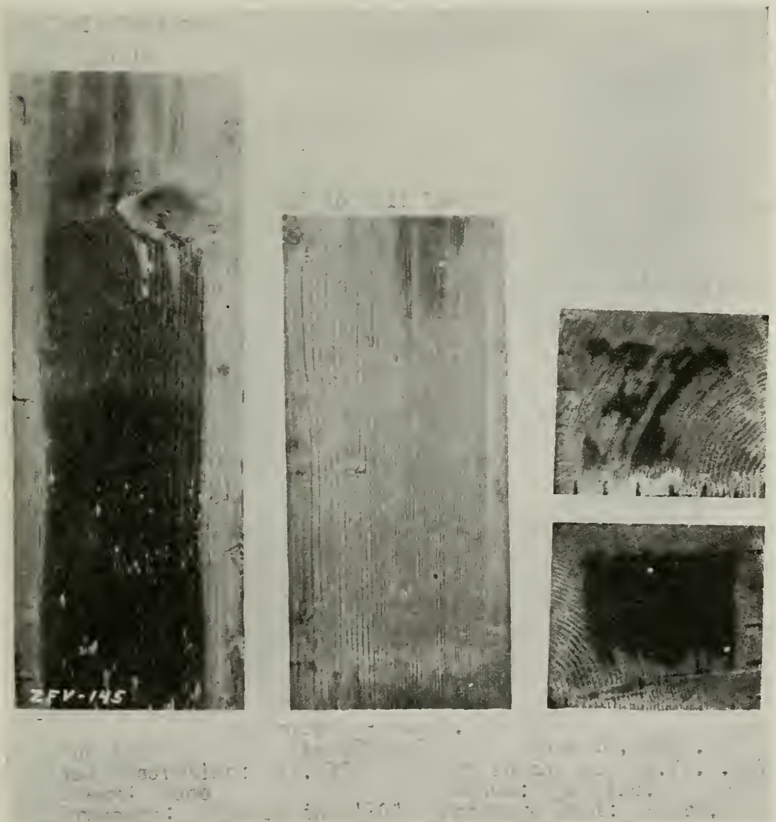
SAWN DOUGLAS FIR TIE—UNPERFORATED



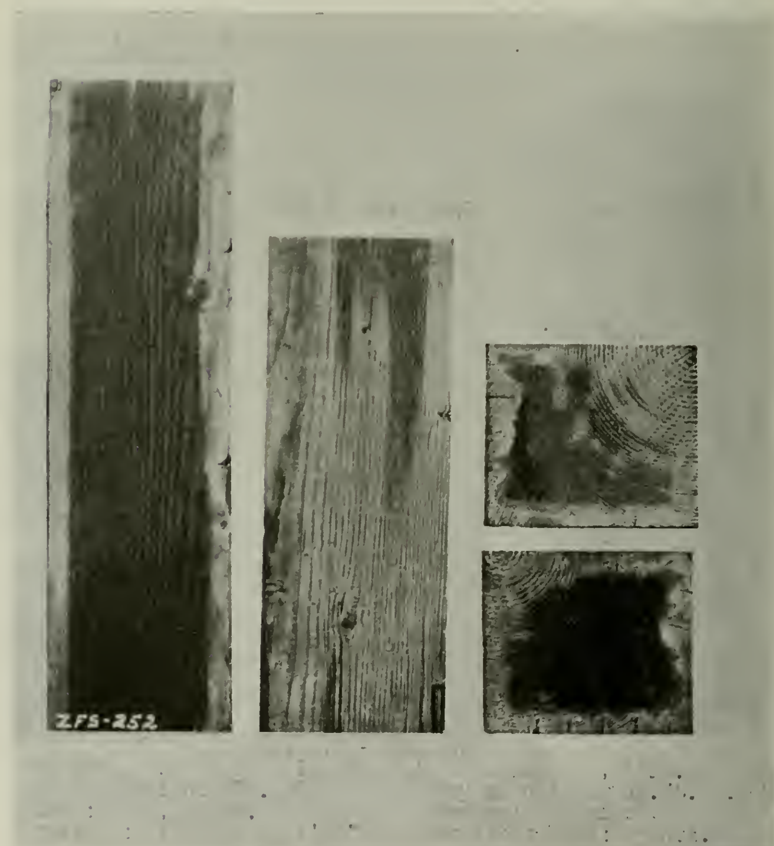
Sawn Douglas Fir Tie—Unperforated



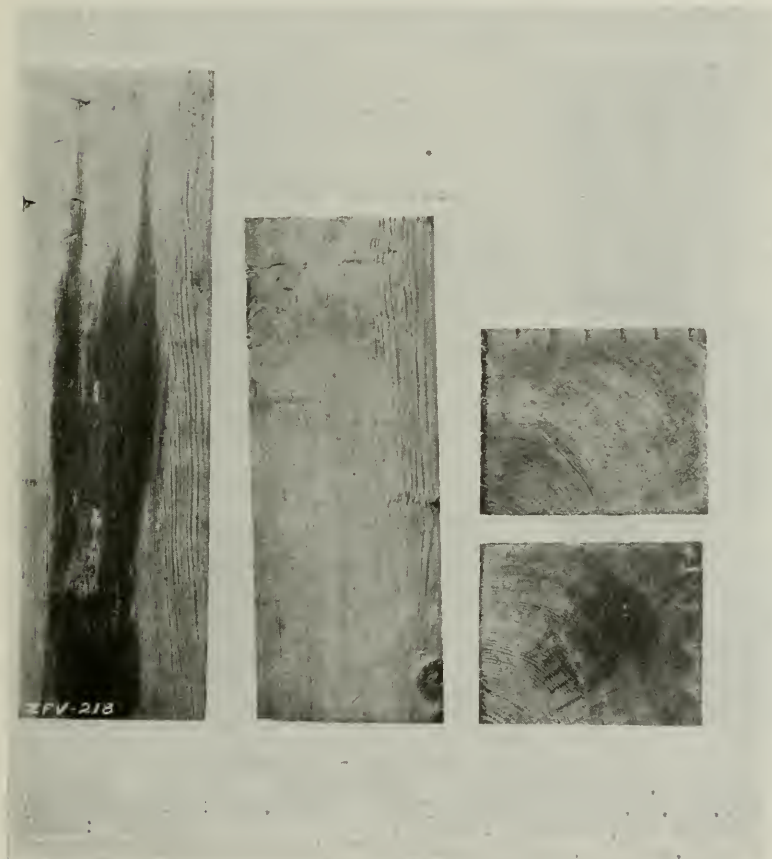
Sawn Douglas Fir Tie—Perforated 1¼-Inch Center to Center



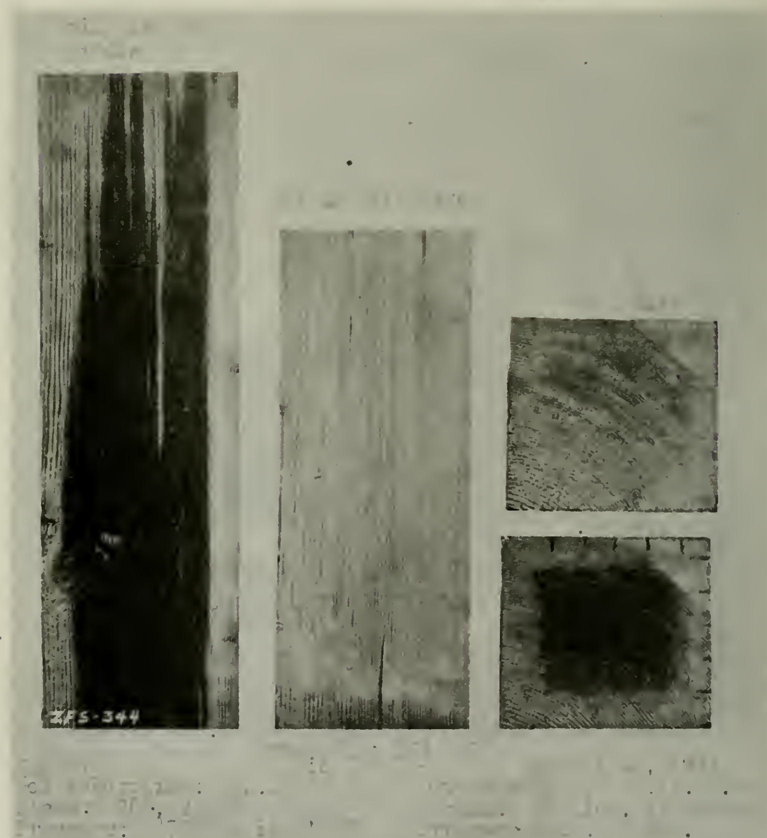
SAWN DOUGLAS FIR TIE—PERFORATED 1¼-INCH CENTER TO CENTER



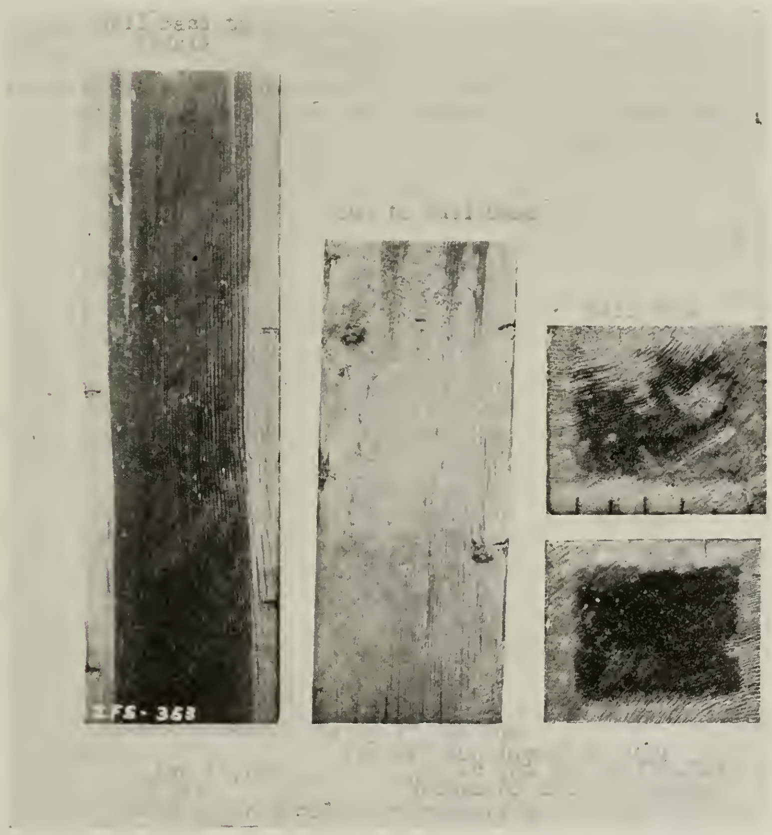
Sawn Douglas Fir Tie—Perforated 1¼-Inch Center to Center



Sawn Douglas Fir Tie—Perforated 1¼-Inch Center to Center



Sawn Douglas Fir Tie—Perforated 1¼-Inch Center to Center



SAWN DOUGLAS FIR TIE—PERFORATED 1¼-INCH CENTER TO CENTER

Creosote Treatment of Douglas Fir Ties

Your Sub-Committee recommends that this subject be given further consideration and report made on this treatment next year. The development of the creosote treatment for Douglas Fir ties goes hand in hand with the development of the perforating process and while ties perforated as above described fit in well with the zinc chloride treatment, yet it is our opinion that Douglas Fir offers greater resistance to the penetration of creosote than it does to the zinc chloride solution, and for this reason it is quite probable that a closer spacing of the perforations will be desirable for creosote treatment, and when such spacing of perforations is once decided upon the details of the creosote treatment can be arranged accordingly.

Appendix D

PACIFIC COAST MARINE PILING

W. H. Kirkbride, *Chairman;* A. Gibson, J. F. Pinson, *Sub-Committee*

Introduction:

The following report is the first to be submitted by the above Sub-Committee, and has been arranged as an introduction to the work coming within its scope dealing with the preservation and development of marine substructures. The extensive timber lands of this Coast offer an almost unlimited supply of material for such structures, but the destructive work of marine boring pests has reached such proportions that effective preservation must be secured, or the value of this timber be greatly reduced for such purposes. It is generally believed that the Pacific Coast has suffered the severest marine borer attack of any part of the United States seaboard, and it is evident therefore that the greatest effort to resist them must be made in this locality.

The existence of these pests on this Coast has been known since the beginning of marine construction, and their action has been under the observation of individual investigators for about 30 years. But heretofore no thoroughly organized, scientific effort has been made to study their separate characteristics and boring proclivities, with the idea of both resisting and exterminating them, if possible. This must not be construed as depreciating the splendid work of these past investigators, who, among innumerable protective agencies, evolved the creosoting process, which remains today the most effective timber pile preservative. The Sub-Committee simply desires to make it clear that for some time to come its work must be confined for the most part to investigation and to the correlation of existing data, and that definite recommendations in regard to preservatives or construction materials cannot be made until after the results have been carefully analyzed.

Pacific Coast Marine Borers:

Historical—The presence of marine borers in several Pacific Coast harbors has been known for half a century. But, on the other hand, certain other harbors have been free of them until recently. The increase in their destructive activity has taken place simultaneously with the increase of shipping at each harbor, indicating that to a certain degree they have been brought in by the ships from their original breeding places and have then established themselves in the new locations. The agencies of this transplanting process may have been the hulls of wooden ships, salt water tanks of all ships, log booms, and driftwood. As an evidence of the possibility of such transportation, the engineers of a California sugar refinery discovered that teredo were destroying a redwood salt water tank located on the ninth floor of the refinery. The larvae had been pumped in through the salt water pipes and, having fastened themselves to the side walls, soon began to bore into the wood.

It is natural, therefore, that with proper conditions for their propagation, such as seems to exist on the Pacific Coast, the larger ports of Puget Sound and San Francisco Bay were the first to become seriously infested, and were the first places where protective efforts were made. By 1880 untreated piling had proven itself impractical in certain localities, and creosoting and numerous forms of surface covering were adopted. At the same time new pile material, other than wood, began to be introduced with varying success. Creosote was selected in the majority of cases, because of its comparative cheapness, and because it had already demonstrated its superiority over the majority of other preservatives. In this class were innumerable ones which had been tried and discarded in Europe and elsewhere.

The absence of creosoting plants, which involved a considerable investment and had previously been considered unnecessary, led to much imperfect treatment, the majority of preservatives being applied on the surface by hand. It was soon demonstrated that this method only caused a thin outer shell to become impregnated, and that the slightest flaw in this armor opened the way for a complete invasion by the marine borers. The next step was the establishment of creosoting plants by private firms, wherein the treatment could be carried out more thoroughly by placing the piles in sealed retorts and injecting the oil. These privately owned plants now handle all the Pacific Coast business (with the exception of that of one railroad, which operates its own plants) and are located for the most part in the northwest territory around Seattle.

In 1889 the Southern Pacific Company completed a temporary creosoting plant at San Pedro, where piles were to be treated for a projected wharf in the vicinity. All material used was Douglas Fir, and had been thoroughly air-seasoned by being laid out along the beach for about a year. It was then treated by the "Bethel" process, in which the average injection of oil was 14.17 lbs. per cubic foot.

Some of the piles were shipped by rail to Oakland, where they were driven in 1890 in the Old Long Wharf. The balance were used in the Santa Monica Wharf, which was completed about 1891. Both of these structures have been removed within the last few years, the former in 1919 and the latter in 1915; but a majority of the original piles were found to be perfectly sound and having been redriven elsewhere are still in service after having successfully withstood the attack of marine borers for 30 years.

These are not the only cases where creosoting of piles has achieved marked results. The Southern Pacific Company built a permanent creosoting plant at Oakland, which began to operate about 1891. Piles from this plant were driven in various docks on the east side of San Francisco Bay, including docks of Old Long Wharf, and three other structures, the last of which was completed in 1904. The majority of these piles are still in service, after having been in service from 17 to 30 years.

The above piles are under observation, and will be reported on regularly by this Sub-Committee.

A recent report issued by the San Francisco Bay Marine Piling Committee comments, among other things, on the nature of progress which has been made in this locality in combating marine borer attack. Attention is called to the fact that engineering effort and public interest have been stirred to action in almost regular cycles of about 10 years each. The direct cause has generally been the failures of some structures, the replacement of which has called for a great new expenditure. Each cycle has produced a new pile development, upon which hopes for a final solution have been based, and activity has again subsided to await results.

It is this sort of spasmodic effort which present organizations will try to eliminate by maintaining continuous correlated study; and new developments should constantly arise because of the stimulated interest which already is under way.

Pacific Coast Investigations:

The San Francisco Bay Marine Piling Committee has organized and launched an extremely thorough program of investigation. Their Survey, published in 1921, established a precedent of skillful, authoritative analysis and has elicited unlimited praise from all sources. Their further findings and general data have been placed at the disposal of the present Sub-Committee, and the indebtedness to them is hereby gratefully acknowledged.

In addition to the above-mentioned organization, the Sub-Commitee is in touch with investigations now in progress along the entire coast line. Piling in existing structures is being observed in the waters surrounding Vancouver Island. Puget Sound, Tillamook, Yaquina, Coos, San Francisco, San Pedro and San Diego Bays. Test piles were driven in 1919 and 1920 by each of the following:

The Northern Pacific Railway Co., at Seattle.
The Northwestern Pacific Railroad Co., at Tiburon, in San Francisco Bay.
The Southern Pacific Co., at San Pedro and San Francisco.
The Santa Fe Railway Co., at San Diego.

Under the direction of the San Francisco Bay Marine Piling Committee, hydrographic, biological, chemical and engineering investigations are being made. Likewise, the War Department, United States Forest Service, and various university and industrial bodies are co-operating. Much valuable data exists and awaits the investigators who shall uncover it and gather it together.

Starting at the north, the Esquimault and Nanaimo Railway Company have had considerable experience with timber piles in Victoria Harbor, and adjacent waters around Vancouver Island. For 14 years they have been using Australian "Turpentine" piles, which do not rot, and which have been found to resist the attack of marine borers, with the exception of an almost imperceptible action of limnoria on the surface. They have also tried various means of handling Douglas Fir, and for example favor the growths cut from rocky land which are highly resinous, particularly at the butt. They have found that additional length of life can be secured by driving these piles butt end down so that the most resinous section comes in the range of the greatest attack, from mud line to low tide level.

The Northern Pacific Railway has conducted considerable investigations of borer action at Seattle. A complete diver inspection has been made of all their wharf piles, and increment borings have been taken. Complete records of this examination were made showing progressive stages of destruction of the piles. As an example of the severity of borer action, they make the following statement:

> "We have many samples of piling completely honeycombed with teredo holes, through a heavily impregnated ring of creosote."

As already stated, this railroad has driven a set of test piles in a dock at Seattle, and is co-operating with this Sub-Committee in recording results of service observations.

The Oregon-Washington Railroad and Navigation Lines have wharves at Seattle, Tacoma, Ilwaco and Nahcotta, where they consider the creosoting of piling essential in all cases. The results of their investigations are interesting for many reasons, including that of using green piles without air-seasoning, and favoring water jetting in driving, where possible.

The Southern Pacific Company has marine structures at Tillamook, Yaquina, Coos, San Francisco and San Diego Bays, as well as elsewhere. A characteristic of this Company's work is that of being the only road which operates its own Pacific Coast pile treating plant. Furthermore, it is in position to raft piles or handle on cars to the job direct from the creosote plant, thus eliminating to a very large extent the liability to damage from dogging and frequent handling. A third point is that they have positively succeeded in turning out creosoted fir piling which is still serving, after having been in place 30 years. As already stated, this railroad has also driven test piles for observation under the direction of this Sub-Committee.

The Northwestern Pacific Railroad Company has marine structures in San Francisco Bay, Petaluma Creek and elsewhere. This railroad has demonstrated an interesting use of metal sheathing for pile covering, some of which was tried as far back as 1884. Some of their metal covered piles driven at a more recent date are still in service, after being in place from 15 to 20 years. This road is also co-operating with this Sub-Committee in the matter of service test piles driven by them, at Tiburon.

The San Francisco-Oakland Terminal Railways have a long pier extending into San Francisco Bay from the east side. They have tried several forms of pile covering including wood battens and concrete, and in one case found untreated eucalyptus piles, which had been driven with bark on in shallow water, to be still sound after 15 years of service. These were removed and not redriven when the Company altered its pier, thus making it impossible to observe the possibilities of further service.

Among the numerous industrial firms actively co-operating in the project to combat the marine borers is the California-Hawaiian Sugar Refining Company, located at Crockett, on Carquinez Straits, a body of water tributary to San Francisco Bay. The experience of this Company is particularly noteworthy for the reason that the water in the Straits was originally fresh at their location, and later became salt because of inroads of irrigation projects on the river above, and because of the years of drought. Their shipments of raw sugar from the Hawaiian Islands create extremely heavy loads on their wharves and warehouses, all of which are supported on piles. The arrival of salt water brought with it a very severe attack of marine borers, and after a failure of a wharf section, the Company set about to redrive all foundations. New wharf and warehouse floors were made of reinforced concrete, supported by groined arches, which in turn rested on the piling. Timber piles were used where the bottoms of groined arches penetrated several feet below the mud line, and reinforced concrete piles where they would be exposed to salt water.

The Santa Fe Railway Company has a number of marine structures in San Francisco Bay and at San Diego, and has constantly been in touch with coast investigations. They are participating in the continuous pile service test already referred to, and have driven a set at San Diego for observation.

The entire waterfront of San Francisco is under the control of the California State Board of Harbor Commissioners, who began to function in 1863. Since that time, they have directed all building in this section of the harbor, and their files constitute one of the most valuable records on Pacific Coast waterfront construction in existence. In this respect they are fortunate, for the reason that the Ferry building, which houses their offices, was not destroyed by the great fire of 1906. A majority of other organizations with general offices in the heart of the City, lost all their records, and now only have those dating from that year. Another feature which has helped to make their records available is the biennial reports which have been published regularly, and now can be referred to. The Harbor Board is in direct control of a great number of marine structures, and their experiences over such a long period have demonstrated many valuable facts.

The Board has just issued a report on Piling Service Records which includes much interesting information, some of which is briefly noted in the following:

A complete diver inspection of their wharf piling has disclosed the astonishing fact that 80 per cent. of the creosoted pile failures were attributable to dog holes, permitting attacks of marine borers. The Board was the first large organization to use the Holmes patent cylinders, which consist of casting a concrete cylinder around a single pile or group of piles. The report states that the single green piles encased in concrete are successful if properly designed and constructed. They also report on the failure of a group of 1,200 eucalyptus piles, driven in 1908. The failure was due to breakage and to Xylotrya attack, and all were replaced in 1912.

Biological.—In order that progress may be made in detecting and reporting the presence and activity of marine borers, it is essential that their individual characteristics so far determined be given as widespread publicity as possible. Unfortunately, little is known and less has been written on the subject. The layman has been content to merge all of the Mollusca group into one type and call them "teredo" and all of the Crustacea group into one type and call them "limnoria." This has served for all practical purposes to the present time, but since every source must be utilized henceforth in gathering information, it would be well to have a distinction drawn between Teredo and Xylotrya, and between Limnoria and Sphaeroma.

Two rough means are available for this purpose: The physical appearance of the borer; and the character of the burrows created by them, when a sufficiently large number are present. A brief statement of characteristics of the more common borers is given in the following, and has been prepared from descriptions furnished by Professor Charles A. Kofoid, of the University of California. At the end of these descriptions a tabulation has been prepared to provide convenient means of identification.

Teredo Navalis Linnaeus (Mollusca Group):

This borer when full grown is usually from ¼ to ⅜ inches in diameter at the head, and 4 to 12 inches in length. It may be found with greater length, but the above is more common, and it is desired here to show this form as the small borer, as compared to the larger Xylotrya. Its color is whitish and translucent. The boring action is accomplished with a pair of bi-valve shells at its head, which open and close "rubbing" or "filing" away the wood. At the tail are attached small, flat, double-pointed "pallets," which prevent intruders from entering its burrow. These latter are the most distinctive features of their bodies, as compared to those of the Xylotrya, which serve for the same purpose, but are long and like feathers.

The Teredo first appears as free swimming larvas which have been released from the body of the female. Moving about in the water, they soon develop the pair of bi-valve shells, and with this additional weight tend to settle near the mud-line. If not destroyed by other forms of marine life, and if the water contains sufficient food mourishment, they ultimately discover weak spots or irregularities in piling, or other timber substructures; and, having attached themselves, begin to bore in. They enter the piles horizontally through minute holes, the range of attack usually being between mud-line and low-water. Having entered the pile they turn and work longitudinally with the surface in parellel symmetrical lines, their greatest activity being in the outermost three inches of the pile, but in this respect it is interesting to note that at Port Costa, they attacked in such large numbers that the entire pile cross-section was destroyed. Teredo seem to be able to thrive in brackish water, and are able to survive under alternating flows of fresh and salt waters. The burrow walls one lined with a whitish nacre secretion which readily can be scaled off.

Teredo diegensis Bartsch (Mollusca Group):

This form seems to be confined to the California coast, and has only been found in small numbers to date. Since it has not yet been a very destructive agency, its characteristics need only a brief description. It is the smallest of the Mollusca group, being only about 4 inches long. Other features are like those of the Teredo navalis given above, with the exception of the distinctive tail pallets. These are fork-shaped, with two long points, as compared to the short points of the Teredo navalis.

Xylotrya setacea Tryon (Mollusca Group):

This borer is the largest of the Mollusca group, usually being about ¾ inch in diameter at the head and about 2 feet long. The color, boring action, and development from the larval stage are similar to that of the Teredo. The pallets are very distinctive, however, two of which are attached at the tail and have the appearance of feathers, often about 1½ inches long. After having entered the wood horizontally through a minute hole, the borer rapidly expands to its full diameter. It then proceeds to bore in any direction, changing its course abruptly and often selecting the pile center section, apparently because of having it undisturbed by Teredo who are working in the outer shell. This abrupt changing of course distinguishes it from the Teredo. The Xylotrya does not seem to be able to live in polluted salt water, and is usually found where the water is clear and of high salinity.

Limnoria lignorum Rathke (Crustacea Group):

This is a very small, flat, oval-shaped borer, with length about ¼ inch and width about 3/32 inch. The back is covered with several smooth, curved armor "scales" which lap over and slide upon each other and are capable of adapting themselves to any curve of the animal's body. (For purposes of description, a popular comparison can be made to the commonly-known back armor of the armadillo.) It has two pairs of antennae, and seven pairs of legs. Under the head are four pairs of small biting "claws" with which it tears away the wood. It has no free swimming larval stage, and is apparently transplanted by the female moving from timber to timber and depositing eggs. These in turn hatch out and continue the propagation. Limnoria often cover a surface completely, there being possibly 200 on a square inch. Once having gained possession of a surface, they can succeed in repelling other borers. The area attacked is usually between high and low tide levels. A characteristic of the Limnoria is that it thrives in polluted water of high salinity.

Sphaeroma pentodon Richardson (Crustacea Group):

This borer has the same general appearance as the Limnoria, but is much larger, thus bearing a similar relation to the latter, as the Xylotrya does to the Teredo. Its width is about ¼ inch, and its length about ½ inch. The color varies from dark olive to reddish brown. Its smooth, sliding back armor "scales" can easily be seen, and when disturbed it can roll itself into a ball about ¼ inch in diameter. Its burrow is about ½ inch in diameter and usually remains near the pile surface, following the softer portions of the wood. This burrow being near the surface is quickly attacked by the Limnoria, and hence often obscured by being eaten away irregularly. The range of attack is usually between high and low water, and the borer thrives in all conditions of salt water, brackish, polluted, or of clear, high salinity.

From the foregoing it can be seen that the destruction of an unprotected timber pile can be complete if the borers enter the locality. Teredo will general honeycomb the outer three inches between mud-line and low water. Xylotrya will reduce the center section between mud-line and low water; Limnoria will eat off the pile between high and low tides, and Sphaeroma will burrow into the surface shell between high and low tides. Piles in brackish water can be destroyed by Teredo and Sphaeroma; in polluted water by Limnoria and Sphaeroma, and in clear water, at high salinity by all four types.

The foregoing also shows that the critical stage of marine borer growth for which all piles must be prepared is the larval condition. If the larvae can be repelled because of finding no untreated wood, or no irregularities or crevices in the surface, long life of the piles may be expected.

The following tabulation of Pacific Coast harbors gives the names of marine borers already discovered, and a statement of the length of life of creosoted fir piling. "Teredo" have commonly been reported at points where it is practically certain none exist, but rather Xylotraya of the teredo family. It is also probable that Sphaeroma exist at all these points but were not reported because of difficulty of inspection or failure to recognize them. The minimum life of creosoted piling roughly indicates the severity of attack, if treatment is imperfect or if a blemish is present allowing borers to secure a hold. The maximum life indicates the possibilities of the better quality of such piles. Untreated piling has not been listed because its life is negligible at these points, except at Tillamook, Yaquina and Coos Bays, where borer attack is light and probably sporadic. It is of interest to note that the Teredodiegensis was given its name by Bartsch because of having been found in San Diego Bay.

Alaska.—Xylotrya have succeeded in establishing themselves in Alaskan harbors and have created much damage. They appear to thrive in the cold, fresh, unpolluted salt water of that region.

VANCOUVER ISLAND.—Limnoria and Xylotrya are present and very destructive in the harbors of Ladysmith, Nanaimo, Nanoose, and Port Alberni, and appear to be growing more active in the last few years. Untreated fir piling has been destroyed in less than a year and preservative methods have been in use for many years. Victoria harbor does not suffer as severely as those mentioned above because of the volume of fresh water flowing into it. It is in this vicinity that Australian turpentine piles have been used. After 14 years of service they are reported to have completely resisted the Xylotrya, and to hav allowed only a slight Limnoria surface action.

TABULATION SHOWING MEANS OF IDENTIFICATION OF FOUR MARINE BORERS COMMON TO THE PACIFIC COAST

Name of Borer	Diameter of Burrow	Pile Surface Indication	Vicinity of Most Frequent Attack	Elevation of Attack	Physical Identification	Water Frequented
Teredo....	¾"-⅜"....	....	Outer 3"....	Mud Line.. Low Tide.	Short, double-point pallets...	Brackish or High Salinity, Unpolluted.
Xylotrya..	¾"-⅞"....	....	Complete	Ditto..... Section..	Two long, feather-like pallets....	High Salinity. Unpolluted.
Limnoria..	1⅟16"......	Surface Erosion..	Perimeter..	Low Tide. High Tide.	Small size 3⅟32" wide x ¾" long, flat, oval shape. Sliding back "scales." Light translucent color..........	High Salinity. Polluted or Unpolluted.
Sphaeroma	½"........	Surface Burrows.	Perimeter..	Low Tide. High Tide.	Size ¾" wide, x ½" long, flat, oval shape. Sliding back "scales." Dark olive to reddish brown color....	Brackish or High Salinity, or Polluted.

Note—Where fresh water flows into salt water possibility of presence of marine borers is indicated by gathering of barnacles or common forms of molluscs on pile surface.
Pile surface indication of Teredo and Xylotrya is difficult with naked eye, but minute en trance holes may be detected with magnifying glass.

MARINE BORERS AND LIFE OF CREOSOTED FIR PILING AT VARIOUS PACIFIC COAST HARBORS

	Marine Borers Reported		Life of Creosoted Fir Piling
Alaska.............	Xylotrya		No report
Vancouver Island...	Xylotrya	Limnoria	10–15 years
Puget Sound........	Xylotrya	Limnoria	5–20 years
Tillamook Bay.....	Xylotrya	Limnoria	No report
Yaquina Bay.......	Xylotrya	Limnoria	No report
Coos Bay..........	Xylotrya	Limnoria	No failures to date
	Teredo Navalis		
San Francisco Bay..	Xylotrya Teredo Diegensis	Limnoria Sphaeroma	8–30 years
San Pedro Bay.....	Xylotrya Teredo Diegensis	Limnoria Sphaeroma	10–30 years
San Diego Bay.....	Xylotrya Teredo Diegensis	Limnoria Sphaeroma	No report

Puget Sound.—The extensive lumber business of the Sound, together with the innumerable timber marine wharves built of untreated or imperfectly treated piling, have permitted the Limnoria and Xylotrya to establish themselves firmly at many points around this body of water. Tide and currents coupled with the great depth of water serve to reduce the element of local pollution, and to maintain a high, clear salinity, thus providing the most favorable condition for the marine borers. The infestation seems to have grown worse in recent years, and at present untreated fir piling will be destroyed in less than a year.

Tillamook and Yaquina Bays.—Limnoria and Xylotrya are reported at both of these bays, but no definite data is available as to the degree of infestation.

Coos Bay.—Limnoria and Xylotrya are present in limited numbers, and their attack seems to fluctuate with lapses of comparative inactivity. The Southern Pacific Company has a structure here which contains creosoted fir and untreated cedar piling, the latter having been placed in 1912. These cedar piles consisted of sound "dead timber" cut from land which had been burned over by a forest fire. The balance were of freshly cut green timber. Recent inspection disclosed the interesting fact that the "dead timber" had been attacked, but that the green timbers were practically unaffected.

San Francisco Bay.—This harbor has probably suffered the greatest inroads of marine borer attack of all on the Pacific Coast, and the subject has already been given widespread publicity in engineering publications.

Shipping activity and the harbor's peculiar geographical configuration have allowed the borers to become well established. San Francisco Bay and the adjoining San Pablo Bay have a total length of about 80 miles, with an average width of about 10 miles. The only inlet from the sea to this great body of water is through the narrow gate, and the result is that a tremendous current is created at the ebb tide. This current rushes by the whole San Francisco waterfront, thus causing extreme borer action, except where sewers pollute the water.

The water of the San Joaquin and Sacramento Rivers was formerly of sufficient volume to hold back the salt water from San Pablo Bay, and to prevent it from entering Carquinez Straits, but extensive agricultural development of the Sacramento Valley, including rice culture, and the years of slight rainfall, have served to reduce the amount of fresh water reaching the Straits. As a result, the water from the juncture of San Pablo Bay and the Straits, through Suisun Bay to the point where the above-mentioned rivers meet, a distance of about 25 miles, has become brackish. A great number of industrial wharves had been built within these limits, using untreated piling, and the resulting destruction from Teredo navalis and Sphaeroma has already run in millions of dollars. The activity of both borers give practically no surface indications, and the imminent danger was not realized until wharves and warehouses collapsed.

The condition of borer infestation on the east side of San Francisco Bay has been disclosed by investigation which attended the removal of the Old Long Wharf of the Southern Pacific Company in 1919. This wharf, originally completed about 1871, consisted of five docks, A, B, C, D, and E, radiating from the approach pier, somewhat as the fingers of a hand, and was first built of untreated fir piling. By 1889 the borer action had become so severe that it was decided to re-drive the docks with creosote piles. This was carried out between the years 1890 to 1901, there being driven an estimated total of about 14,000 creosoted piles, a few of which had been treated at the Southern Pacific Company's temporary plant at San Pedro, and the balance at their permanent plant at Oakland.

Changes in the Oakland City waterfront necessitated the removal of the above wharf in 1919, and when this was done, a majority of the creosote piles were found to be sound and unaffected by marine borers. Replacements in the intervening period had been too small in number to be appreciable. The following tabulation reflects the results of inspection of the piling:

Creosoted Piles in Dock A, Driven in 1890:

Removal of piling completed before inspection was inaugurated: Thirty-three creosoted piles showed following condition:

		Per cent.
Sound, fit to redrive	22	66.67
Slightly attacked between low and high water	6	18.18
Severely attacked, between low and high water	3	9.09
Completely destroyed, between low and high water	2	6.06
Total number examined	33	100

Creosoted Piles in Dock B, driven in 1898:

Removal of piling completed before inspection was inaugurated.

Creosoted Piles in Dock C, Driven in 1897:

		Per cent.
In sound condition, fit to redrive	333	63.67
Severely attacked, between low and high water	74	14.15
Completely destroyed, between low and high water	116	22.18
Total number inspected	523	100

Creosoted Piles in Dock D, Driven in 1899:

		Per cent.
In sound condition, fit to redrive	829	76.06
Severely attacked between low and high water	162	14.86
Completely destroyed, between low and high water	99	9.08
Total number inspected	1,090	100

Creosoted Piles in Dock E, Driven in 1901:

		Per cent.
In sound condition, fit to redrive	1,900	76.46
Severely attacked, between low and high water	240	9.66
Completely destroyed, between low and high water	345	13.88
Total number inspected	2,485	100

SUMMARY—*Docks C, D and E.*

		Per cent.
In sound condition, fit to redrive	3,062	74.72
Severely attacked, between low and high water	476	11.61
Completely destroyed, between low and high water	560	13.67
Total number inspected	4,098	100

All the sound piles were redriven elsewhere. There is no reason for believing that the Summary of Docks C, D and E would have been greatly affected had it been possible to include piles from Docks A and B. Hence it is likely that 75 per cent. of the original creosoted piles are still in service. Attention is also called to the fact that many of those slightly attacked were redriven inshore, with the result that about 80 per cent. of the original total are still serving.

Investigations of the Dumbarton Cut-Off trestle of the Southern Pacific Company, at the extreme south end of the Bay, have disclosed the presence of Xylotrya, Teredo navalis, Limnoria and Sphaeroma.

Teredo diegensis has been found at only one point in the Bay, at the Schaw-Batcher ship yards, near South San Francisco, on the West side.

The foregoing briefly outlines the manner in which San Francisco Bay has become infested with five forms of marine borers, with conditions such that they can thrive and work severe damage. The brackish water at the north in Carquinez Straits and Saisun Bay is infested with Teredo navalis and Sphaeroma, and the water of San Francisco Bay proper, with high salinity, is infested by both of the above, together with Xylotrya, Limnoria and Teredo diegensis.

San Pedro and San Diego Bays.—Both of these harbors have suffered attacks of Xylotrya and Limnoria, with Teredo diegensis present in a minor degree. Test piles were driven at both places, including untreated piles, old creosoted piles from Long Wharf, and freshly creosoted piles. Those untreated have already been severely attacked by Limnoria, and one of the Long Wharf piles at San Pedro shows slight evidence of borer action.

Tests.—The following list shows special service tests now being observed by the Sub-Committee:

1. *Four sets of 7 piles each driven as follows:*

March, 1920, Northern Pacific Ry. Co.....................Seattle
September, 1919, Northwestern Pac. R. R. Co............Tiburon
September, 1919, Southern Pacific Company...........San Pedro
June, 1920, Santa Fe Railway Company..............San Diego

Each set includes 1 untreated fir pile, 2 freshly creosoted fir piles, and 4 creosoted fir piles taken from Old Long Wharf in 1919.

2. Twelve creosoted Douglas fir piles from Old Long Wharf, driven as brace piles in Southern Pacific Company Wharf No. 2—Oakland Pier, October, 1919.

3. Sixteen eucalyptus piles driven in dolphins of Alameda Ferry Slip of Southern Pacific Company, 1921.

4. Sixteen eucalyptus piles driven in dolphins of Oakland Auto Ferry Slip of Southern Pacific Company, 1921.

5. Eighteen dolphin piles in Georgia Street Wharf, South Vallejo, of Southern Pacific Company covered to above high water with "Moran" paint, 1921.

6. Eighteen dolphin piles in Georgia Street Wharf, South Vallejo, of Southern Pacific Company, covered to above high water with "Paraffine" paint, 1921.

Insufficient time has elapsed since the inauguration of the tests above enumerated to allow a conclusive report of definite results. All of the creosoted piles of Tests Nos. 1 and 2 reported on to date are in good condition. One of the old Long Wharf creosoted piles at San Pedro shows a slight Limnoria action. The untreated pile of the set at this location has been eaten by Limnoria to a depth of 2 inches, near low-tide level.

The San Francisco Bay Marine Piling Committee has established a laboratory and aquarium on the Oakland Pier Wharf of the Southern Pacific Company, where living marine borers can be observed working in specimens of wood submerged in glass tanks. This gives an excellent opportunity to see the syphon which the Teredo, or Xylotrya, extend out of the entrance to their burrows into the water, and through which they obtain their nourishment. This is about the only manner in which this delicate syphon can be seen because of the fact that the borer draws it back into the wood at the slightest disturbance, or when taken out of salt water. The ejection of wood "sawdust" can also be watched, and likewise the breeding process.

In addition to these tests, your Sub-Committee has under observation numerous structures of creosoted piling just completed by the Southern Pacific Company, viz.: Auto Ferry Slip, Oakland; new Ferry Slip, Port Costa; Ferry Slip, Benicia; etc.

In conclusion, the Sub-Committee makes the following recommendations:

1. That the co-operation of Pacific Coast bodies in position to contribute data on the condition of marine borers in the various harbors be further solicited.

2. That standard Service Records be prepared and that owners of marine wharves be requested to institute them, and place the results at the disposal of this Sub-Committee.

3. That publicity be given to the nature of the individual marine borers under investigation, so that correct identification may be possible.

4. That temperature and salinity tests be made at regular intervals in the main harbors.

5. That efforts be made to co-operate in the movement now under way to cause the removal of unused marine structures, which are the breeding places of marine borers.

6. That biological study of the marine borers be continued and given as wide publicity as possible.

7. That the analysis of all structural timber used for marine substructures be investigated to ascertain qualities of absorption and adsorption.

8. That continuous tests be made by submerging timber treated with creosote oil in several degrees, ranging from the portion in which all the toxic ingredients have been removed to that of the full oil.

9. That continuous tests on the various commercial forms of surface coverings be made.

10. That service records and general data, including the element of cost, on the various forms of piling material other than timber be investigated.

11. That construction methods be further developed and the theories be disseminated among construction forces to cause a more careful handling of treated material about to be put in place.

Appendix E

RESEARCH WORK ON MARINE PILING

Hermann von Schrenk, *Chairman;* Z. M. Briggs, S. D. Cooper, A. B. Ilsley, W. H. Kirkbride, *Sub-Committee.*

Wooden piles used in marine construction have since the earliest days been subject to attack by various forms of marine borers, including members of the genera, Teredo, Xylotrya, Limnoria, Sphaeroma, etc. Very little definite information, however, is available with reference to exact distribution of the various forms, their specific identity, the conditions under which they live, influence of temperature and salinity of waters, the methods of reproduction, feeding habits and kindred points.

The comparatively recent attack on marine structures in San Francisco Bay and in north European waters has brought the subject of marine borers and methods to be used to protect against their ravages prominently to the attention of engineers in all parts of the world. As this is a matter of very vital interest to the members of the A.R.E.A., your Committee has prepared a brief discussion of this subject.

Recent Developments.—While marine borers have been more or less prevalent in the warmer waters tributary to the United States and Canada, no unusual activities were reported until 1917, at which time unusually severe attacks of marine borers were reported by Dr. A. L. Barrows at various points in San Francisco Bay.

The outbreak in San Francisco Bay has continued with remarkable vigor so that to date approximately $20,000,000 worth of damage, more or less, has been reported from that region alone. While these reports were coming from San Francisco similar reports were being received from various north European waters, particularly along the coast of Norway and Sweden, and from various points in England.

The European interest in this subject is very well shown in the recent appearance of a long report by a special committee of the British Institution of Civil Engineers appointed to investigate the "deterioration of structures of timber, metal and concrete exposed to the action of sea-water." The report of this committee, consisting of a volume of 301 pages, with thirty-three plates and thirty-seven figures, deals in part with marine borer attack on wooden structures in all parts of the world and is a valuable contribution to this extremely important problem. Another recent report comes from Denmark, the result of investigations of a joint committee of the Danish, Swedish and Norwegian Engineering Societies.

Recent Investigations.—Stimulated by the recent attacks just referred to, investigations with reference to marine borers have been started in various parts of the world. The first contribution of importance dealt with the San Francisco Bay situation and appeared as a report of the San Francisco Bay Marine Piling Committee of the American Wood-Preservers' Association, in 1921.

This valuable report gives a complete description of the attack, discussion of the various forms of borers found, a description of the physical conditions of San Francisco Bay with particular reference to salinities and temperatures, and suggestions for protective methods to be used. Various activities in Europe are also to be noted, particularly the report of the British Institution of Civil Engineers already referred to, and work done in Sweden and Denmark.

Shortly after the San Francisco Bay appearance it was recognized that environmental conditions probably had a good deal to do with the virulence of attack at that point. The salinity of San Francisco Bay had risen considerably due to reduction on fresh water run-off from the western slopes of the Sierra. Recognizing the probable vital relationship between attacks of marine borers and salinity and temperature of waters in which these organisms thrive, careful determinations as to salinity and temperature have been made in San Francisco Bay and investigations are now in progress to more clearly define the extremes of salinities and temperature under which the various species develop. Recognizing the possibility of unusual marine borer attacks in other parts of the country, your Committee has endeavored to obtain information as to salinity and temperature at various points on the Atlantic, Gulf and Pacific Coasts. In the report by Sumner et al., "A Report Upon the Physical Conditions in San Francisco Bay, etc.," University of California Publications in Zoology, July, 1914, a comparison is made between the annual water temperatures for San Francisco Bay, Woods Hole, Mass., and points in Chesapeake Bay, which are of interest in this connection:

"The mean latitude of these points in Chesapeake Bay is very nearly the same as that of San Francisco Bay. The mean annual water temperature for the former bay, computed from the records referred to, is 14.38° C. (57.89° F.), that for the latter bay being 12.91° C. (55.23° F.). The chief difference between the temperature conditions of these two bodies of water lies, however, in their respective annual ranges. In Chesapeake Bay this amounts to 22.12° C. (39.82° F.), while in San Francisco Bay it is not much more than a third (38 per cent.) as great, being 8.35° C. (15.03° F.). Thus the equable climate for which California Coast is famous is reflected in (we should say, is largely due to) the equable temperature of its coastal waters, though the direction of the prevailing winds is likewise an important factor."

"The resemblance between the Chesapeake Bay curve and that for Woods Hole, Mass., is sufficiently striking. The latter is based upon the monthly means for a period of six years, as recorded at the Woods

Hole station of the Bureau of Fisheries. The vertical distance between the Woods Hole and Chesapeake Bay curves remains surprisingly constant throughout the year, representing, on the average, 3.82° C.

"The mean annual temperature of the surface water in Woods Hole Harbor is 10.56° C. (51.01° F.), or more than 2° C. lower than that of San Francisco Bay. The annual range, computed as for the other points, is 21.50° C. (38.74° F.)."

The same authors in discussing ranges of salinity make the following reference for the same stations:

"For Buzzard's Bay and Vineyard Sound, the density ranged during the observations made in the course of the biological survey of the Woods Hole region from 1.0212 to 1.0244, representing salinities of about 28.7 and 33.0 respectively. The mean for the two bodies of water was about 31.7, a figure slightly higher than that for San Francisco Bay at the station nearest the Golden Gate, and about 15 per cent. higher than that for the Bay as a whole. The absence of any large streams within the Woods Hole region and the free intermingling of the coastal water with the ocean through the tides, are obviously responsible both for the higher mean salinity and for the small range of salinity in that region."

"In Chesapeake Bay, on the other hand, the salinity averages much lower than in San Francisco Bay. Figures are available from twenty-four stations within the upper two-thirds of Chesapeake Bay. These are derived from the "Manual of Oyster Culture in Maryland," by Grave (1912, pages 47-48). We have converted the density figures given in this report into corresponding ones for salinity, making due allowance for the temperatures at which the salinometer readings were made."

"The observations in Chesapeake Bay were made during two periods of the year: (1) during that of greatest rainfall (April 20 to May 8), and (2) during the period of least expected rainfall (October 10 to 26). The mean salinity for all the stations for the first period was 10.86, that for the second being 14.20. The mean of these two figures is 12.53 This represents an average salinity considerably less than half that of San Francisco Bay. It is a lower figure, indeed, than the annual mean for any of our hydrographic stations, even those in Carquinez Strait."

"The mean figure for the Chesapeake Bay station having the highest salinity (average for the two periods) was 18.90, that for the station having the lowest salinity being 4.33."

Aside from a lot of isolated observations very few data appear to be available for the different ports of the Atlantic, Gulf and Pacific Coasts. A few figures which were obtained through the courtesy of Messrs. E. J. Pearson, J. F. Pinson and G. J. Ray are herewith submitted as suggestions:

San Francisco Bay.—See Proceedings of American Wood-Preservers' Association, 1920.

Puget Sound:

Date	Temperature Readings °F Surface	Temperature Readings °F Mud Line
Sept. 19	55	53½
21	54½	53½
23	56	53½
26	56	54
28	54	53½
30	54	53
Oct. 3	56	54
5	54	53½
7	56	53
10	54	53
12	54	53¾

New York Harbor: The following temperatures were taken by the Metropolitan Sewerage Commission of New York in 1912 and 1913 at Pier A, Hudson River mid-stream:

Date 1912	Hour	Feet Below Surface	Temperature of Water in Degrees Fahrenheit
Feb. 27	11:30 A.M.	1	37
27	11:40 A.M.	30	37
March 5	6:25 A.M.	1	33.1
5	6:30 A.M.	30	34
April 3	9:30 A.M.	1	42.1
3	9:40 A.M.	30	43
June 13	10:30 A.M.	1	53
13	10:40 A.M.	30	63
July 11	9:30 A.M.	1	75
11	9:40 A.M.	30	74.5

Date 1913	Hour	Feet Below Surface	Temperature of Water in Degrees Fahrenheit
Jan. 9	8:00 A.M.	1	37
Feb. 18	10:30 A.M.	1	35.1
18	10:35 A.M.	30	35.1
May 29	7:50 P.M.	1	57.9
29	8:10 P.M.	30	57.9
June 11	1:50 P.M.	1	65.1
11	2:00 P.M.	30	63

The following temperatures were taken by the New York Aquarium at the Battery, New York City, at 3:00 p. m. daily in 1920:

	H	*L*
January	42	37
February	37.5	35.5
March	41	36.5
April	45.5	40.5
May	54	45.5
June	62	54.5
July	67	63
August	69.5	67
September	70	67.5
October	67	62.5
November	63	52.5
December	53	44.5

The following temperatures were taken by the U. S. Weather Bureau at Pier 13, North River in 1889:

	Surface	Bottom
January	36.8	36.7
February	32.2	32.3
March	36.7	36.6
April	45.0	44.6
May	57.7	57.2
June	64.7	64.2
July	69.7	69.3
August	70.4	70.0
September	68.2	68.0
October	54.3	53.9
November	50.2	50.0
December	42.4	42.2

Extensive observations of this character are now being planned at various points in the United States. In connection with the figures just given it is pointed out that while temperature and salinity determinations made in regions where marine borers are active are of considerable value, it will nevertheless be necessary to have observations of this character made at such points where the direct biological investigations are being conducted. Definite and accurate knowledge of the environmental conditions as indicated by salinity and temperature when considered in connection with an exact knowledge of the life history of any one particular species will be one of the best methods for determining whether one or the other species of marine borers may be expected at any particular locality. Investigations are in progress in various laboratories dealing with the breeding and food habits of various species of marine organisms concerning which comparatively little is known at the present time. European observations as to temperature and salinity have been more extensive. As a comparison some recent determinations made by the joint Danish, Swedish and Norwegian Committee in the Baltic and North Seas may be of interest. (See paper on Teredo and Limnoria.)

One of the most important phases of the work naturally deals with protective measures. In a general way two general plans have been followed (see in this connection 1920 report of the Committee of the British Institution of Civil Engineers), one to use timbers naturally immune to marine borers and the other to protect wood piles either by impregnation or by other means against the borer attack. So far your Committee has been able to find very few resistant types of timber that have ever been used in North American waters. Through the courtesy of Mr. R. A. Bainbridge, of the Esquimault and Nanaimo Railway, Victoria, B. C., your Committee was enabled to make an examination of an interesting test of Austrian turpentine piles. (Syncarpia laurifolia.) These piles have for years been used in Australia and Asiatic waters and have proven more immune than most other woods to the attacks of marine organisms. At the request of your Committee Mr. Bainbridge kindly prepared a brief statement as to his experience with these piles as follows:

"Replying to your letter on Sept. 8th, asking for further information regarding our experience with timber piles in Victoria Harbor and adjacent waters around Vancouver Island:

"I might say that our experience with Australian turpentine piles during the last fourteen years is very satisfactory, and we find that they resist attacks of teredo absolutely. The limnoria, or water flea as we call it, does affect them to a slight degree, they eat piles from the outside, eating them off to a pencil point. I find that they have made a slight impression on the Australian piles which have now been in service for over fourteen years, but they have made very little headway as yet, the reduction in the diameter of the pile being barely perceptible. Victoria Harbor is not much affected by teredo on account of the large amount of fresh water flowing into the harbor. On the east coast of the island at Ladysmith, Nanaimo, and Nanoose, and at Port Alberni on the west coast, the teredo is very much worse and from recent experience it appears to be more destructive in the last two years than formerly. At all the above points we have Douglas fir creosoted piles in use, and so far we have found they resist the teredo, but they have only been in place for seven years, which is not a sufficient length of time to be able to state how long they will last, but as the tops of these piles will rot out in twelve to fifteen years, it would appear that we will get that much service out of them.

"But the Australian turpentine piles will last indefinitely, as they do not rot, and appear likely to last for one hundred years. The Australian pile referred to is locally called 'turpentine tree,' from the eleo resin produced by the tree. The botanical name is 'Syncarpia laurifolia, Ten.'

"Referring to the assertion that the teredo appears to be getting worse in the last few years, I may mention that at Ladysmith, new timbers were put in a railway trestle approach two years ago, frame bents of Douglas fir on sills completely dry at fairly low tides. These timbers, and the sills especially, have been completely eaten out, being riddled by teredo, and the sills broken in two, and had to be completely renewed. Such extensive damage in so short a time is unprecedented, especially when the timber is bare at low tide. At Nanoose Bay there are some boom sticks fending vessels off dolphins, floating on top of the water, which are partly affected by teredo. This also is an unusual occurrence.

"In conclusion, I may state that in my experience the Australian turpentine piles are the best and cheapest article to use on the Pacific Coast, if they can be procured, but of recent years we have found it almost impossible to get them on account of scarcity of tonnage.

"This obtacle is, of course, now removed, but I am not sure but that the Australian Government has placed an embargo on the export of these piles. There is one other fact I may mention which might be useful, and that is the use of Douglas fir piles got off rocky land and highly resinous, especially in the butt. We drive these piles butt end down so that the portion of the pile above the mud is more resinous than the top portion, and successfully resists the attacks of teredos for a much longer time."

In view of the fact that turpentine piles are usually recommended for use with the bark on, it is interesting to note that Mr. Brainbridge on the subject referred to advices that these particular piles which he used had the bark on, but most of the bark stripped off before the piles were actually driven. An examination made by your Committee during the past summer of the turpentine piles driven in 1911 at Victoria shows them to be practically free from borer attack, whereas Pacific Coast timbers were eaten off in less than a year.

Through the courtesy of Mr. H. N. Rodenbaugh, Chief Engineer of the Florida East Coast Railway, the Committee is in receipt of the following report on the use of Jucaro piling on the Florida East Coast Railway:

"Jucaro timber is found in the Eastern end of Cuba, there being two kinds used for piling, namely 'negro' (black) and 'blanco' (white). Of the two the negro is the better wood. The wood resembles the shell bark hickory in appearance with a bark much like the burr-oak. The heart wood is a dark brown and the sap a light cream color.

The sap will not withstand the action of worms, but the heart wood has been found very resistant against the action of both the Teredo and Limnoria, as will be seen from the accompanying photographs taken of a section from a fender pile in Key West Harbor after seven years' service. It will also be noted that though the sap is honeycombed to a great extent it does not slough off as is the case with pine piling.

To secure the best results from these piling, it is quite necessary to secure green piles and drive them with as little delay as possible, as the timber decays very rapidly when stacked. Above water the sap is quite prone to rot but below water rotting occurs so slowly that it is scarcely perceptible. So far as can be ascertained the heart is very resistant to rot, as is the case with numbers of other tropical woods. However, if the top of the piling is cut off square with a saw and left unbanded, the sun and weather will split the pile in many and long rifts. To overcome this the top should be rounded off and wrapped with several turns of heavy galvanized wire, securely fastened about six inches from the upper end.

These piling drive with considerable spring and are not as easy to drive as green pine or creosoted piles but will withstand considerable pounding. It has been estimated that in bearing qualities it ranks between the Dade County pine and oak. No figures on this feature were obtainable.

These piles are very expensive and the price per foot varies considerably with the length and heart. The high cost is due to poor transportation facilities as they are found in a hilly country quite distant from either railroad or water transportation and have to be handled for a number of miles with oxen; furthermore, there are only certain seasons when they can be gotten out on account of weather conditions.

The latest prices obtainable were on 5500 lineal feet of 50 feet piles purchased by this Company in 1918 which cost, including the freight to Key West, $1.84 per foot.

In view of the fact that creosoted piles have been the chief reliance against marine borers the finding of some old piers built with creosoted piling in San Francisco Bay at the time of the recent outbreak was of unusual interest. Members of your Committee made a preliminary examination at the time that the piles from the Southern Pacific piers referred to were pulled. Note in this connection, preliminary report by F. D. Mattos in 1920 Proceedings of the American Wood-Preservers' Association, Page 148. The oldest piles in these piers were creosoted in 1889, and from then on up to 1897 only creosoted piles were used in the construction of these piers. Due to harbor line changes all piles were pulled in 1919 when it was found that a high percentage of these old piles was still in sound condition, fit for redriving, specifically from Dock C driven in 1897, 63.67 per cent.; Dock D driven in 1889, 76.06 per cent.; Dock E driven in 1901, 76.46 per cent.; or taking all of the piles inspected to the number of 4,098, 3,062 or 74.72 per cent., were sound enough so that they could be used over again. (For details see American Wood-Preservers' Proceedings of 1920, Page 148.) This remarkable record, unequaled by any marine structure in North American waters, could have been due either to the absence of the marine organisms or to effective protection. In order to determine as quickly as possible whether the conditions surrounding these piles were responsible for their long life, arrangements were made to transplant some of these old piles to other waters. Through the courtesy of the Southern Pacific Railway Company, the Santa Fe, the Northwestern Pacific, the Northern Pacific and the Louisville & Nashville Railroads a number were transplanted as per the following detailed statement:

A. T. & S. F. Ry.

The following Douglas fir piles were driven at San Diego, Cal., in Santa Wharf No. 63, in 1919:

S. P. Pile No.	*Mark After Driving*	*Kind*	*Location in Wharf*
50	E 50	Dock E, Long Wharf, Creosoted 1890	Bent 126
2	A 2	Dock A, Long Wharf, Creosoted 1890	Bent 126
33	A 33	Dock A, Long Wharf, Creosoted 1890	Bent 127
7	A 7	Dock A, Long Wharf, Creosoted 1890	Bent 128
	51	Freshly creosoted 1919—Distillate oil	Bent 128
	52	Freshly creosoted 1919—Distillate oil	Bent 128
	53	Untreated (11 rings to the inch)	Bent 127

Northwestern Pacific Ry.

The following Douglas fir piles were driven at Tiburon, Cal., in N. W. P. Co.'s Wharf, in 1919:

S. P. Pile No.	*Mark After Driving*	*Kind*
19	A 19	Dock A, Long Wharf, Creosoted 1890.
28	A 28	Dock A, Long Wharf, Creosoted 1890.
29	A 29	Dock A, Long Wharf, Creosoted 1890.
42	E 42	Dock E, Long Wharf, Creosoted 1890.
	43	Freshly creosoted 1919—Distillate oil (14 lb.)
	44	Freshly creosoted 1919.
	45	Untreated (12 rings on the inch).

An inspection of these piles made in December, 1921, showed that piles Nos. A-19, A-28, A-29, 42, 43 and 44 are in first-class condition, entirely free from attack. Untreated pile No. 45 is badly attacked by species of Limnoria Xylotrya and Teredo. This attack ranges from mud line to high water. The Teredo and Xylotrya attack extends into the pile for two inches.

Southern Pacific Co.

The following Douglas fir piles were driven at San Pedro, Cal., by the Southern Pacific Company in 1919:

S. P. Pile No.	*Mark After Driving*	*Kind*	*Location in Wharf*
5	A 5	Dock A, Long Wharf, Creosoted 1890........	Bent 160
20	A 20	Dock A, Long Wharf, Creosoted 1890........	Bent 7
34	A 34	Dock A, Long Wharf, Creosoted 1890........	Bent 164
	E 38	Dock E, Long Wharf, Creosoted 1890........	Bent 33
	40	Freshly creosoted—Distillate oil..............	Bent 84
	41	Freshly creosoted—Distillate oil..............	Bent 92
	39	Untreated	Bent 155

Freshly treated piles were treated with 14 lb. per cu. ft.

The following Douglas fir piles were redriven as brace piles in Southern Pacific Company's Wharf No. 2 at Oakland Pier, October, 1919:

S. P. Pile No.	Mark After Driving	Kind	Location in Wharf
54	C 54	Dock C Long Wharf Creosoted...........	1897. Bent 36
55	C 55	" C " " "	1897. " 36
56	C 56	" C " " "	1897. " 37
57	C 57	" C " " "	1897. " 37
58	C 58	" C " " "	1897. " 38
59	C 59	" C " " "	1897. " 38
60	C 60	" C " " "	1897. " 39
61	C 61	" C " " "	1897. " 39
62	C 62	" C " " "	1897. " 40
63	C 63	" C " " "	1897. " 40
64	C 64	" C " " "	1897. " 41
65	C 65	" C " " "	1897. " 41

Northern Pacific Railway Company

Condition Report

Test piles placed March 29 and 30, 1920, between bents 47 and 48 and 48 and 49, south side of Pier No. 1, Seattle, Wash. Identification marks on copper plates near top of piles on east side.

N. P. Ry. Marks	S. P. Ry. Marks	
A	Pile 48, freshly creosoted 1919	Oct. 8, 1920. Free from teredo or limnoria.
B	Pile 49, untreated 1919	" " " " " " " "
C	Pile 47, freshly treated 1919	" " " " " " " "
D	Dock E, Pile 46, 1901-1919	" " " " " " " "
E	Dock A, Pile 8, 1890-1919	" " " " " " " "
F	Dock A, Pile 6, 1890-1919	" " " " " " " "
G	Dock A, Pile 32, 1890-1919	" " " " " " " "
H		" " " " " " " "
I		" " " " " " " "
J		Oct. 8, 1920. Attacked by teredo, two points 6′ above ground east side. 12′ above west side.
K		Oct. 8, 1920. Pile "K" not driven.

Under water inspection by diver, Oct. 8, 1920.

H. F. Brown,
Asst. Engineer.

Piles E. F. G.....From S. P. Ry., had been in service in Long Wharf, Oakland, Cal., Dock A, from 1890-1919, 29 years. Removed April 10, 1919.

Pile D...........From same company, had been in service in same wharf, Dock E, 1901-1919, 18 years. Removed April, 1919.

Piles A, C........From same company, freshly treated August, 1919, but not previously used. Boiling process, 14 lbs. per cu. ft.

Pile B............From same company, not treated, but peeled and driven in same condition as received.

Pile H...........Freshly treated, Pacific Creosoting Company, March, 1919, boiling under vacuum. 14 lbs. creosote per cu. ft.

Pile I............Freshly treated, Coleman Creosoting Company, March, 1919, steaming process. 16 lbs. creosote per cu. ft.

Pile J............From Coleman Company, peeled but not treated, driven same condition.

Pile K...........From Coleman Co. with bark on, driven same condition.

Object of test to find out if possible how water in Puget Sound at Seattle compares with San Francisco Bay, Oakland, Cal., with reference to activity of marine borers, also if preservative used in long-lived Oakland piling had a more retarding effect on the borers than that generally used at Puget Sound points.

In addition to the above, whole piles, sections from Long Wharf Piles Nos. 1, 3 and 27, Dock A, creosoted in 1890, were sent to the Louisville & Nashville Railroad at Pensacola, Fla., and were there installed by the Forest Products Laboratory in connection with other treated timber samples for the purpose of testing marine borer action.

During the past summer your Committee examined the transplanted piles at several of these points and received reports from the others. To date the untreated piles only show any signs of attack. Both the freshly creosoted and the old piles are still apparently sound. The next few years should show results one way or the other.

In view of the long resistance of these piles careful studies were made as to the composition of the creosote contained in these piles at the time they were pulled. In the following table the analyses made from a number of these piles are given, divided into the sections taken from the air, water and mud portion of each pile. In addition attention is called to the analysis of an oil sample secured from a hole in the mud section of one of these piles which ran out in liquid form at the time of examination. This oil probably collected in a pocket, and in view of the fact that this section of the pile was protected by the mud the chances for changes during the period of service were very small. In other words, this oil may be regarded as fairly approximating the oil originally used in the treatment of these piles. Further investigations are now in progress with reference to the significance of the findings resulting from the analyses of the extracted oils, upon which it is hoped to give a full report next year.

Analyses of Creosote Extracted from Long Wharf Piles

Pile Number	1			4		
Mark / Exposure	1–2 Air	1–4 Water	1–7 Mud	4–1 Air	4–4 Water	4–8 Mud
% Oil in treated part	43.97	43.17	58.24	38.16	37.93	39.82
% Moisture	11.64	38.53	26.61	14.0	28.6	19.81
Sp. Gr. at 38° C	1.093	1.086	1.085	1.047	1.042	1.044
200° C	0.0%	0.0%	0.5%	0.7%	0.4%	0.4%
210° C	1.0	0.3	0.1	0.9	0.9	0.4
235° C	3.5	2.9	4.2	48.0	43.6	50.6
270° C	13.9	22.0	22.7	16.3	21.5	13.8
315° C	21.7	18.3	19.0	8.2	8.7	10.2
355° C	32.9	32.0	29.5	12.7	13.9	13.2
Residue	27.0	24.5	24.0	13.2	11.0	11.4
Sp. Gr. at 38/15.5						
235–315	1.044	1.037	1.036	1.048	1.029	1.033
315–355	1.112	1.107	1.110	1.105	1.110	1.107
Tar Acids by volume	4.0%	3.2%	2.5%	1.5%	1.3%	......

Pile Number	23			37		
Mark / Exposure	23–2 Air	23–2 Water	23–6 Mud	37–1 Air	37–5 Water	37–10 Mud
% Oil in treated part	26.57	28.59	61.36	57.91	49.39	55.65
% Moisture	20.96	32.30	34.39	13.78	32.52	25.90
Sp. Gr. at 38° C	1.056	1.042	1.041	1.093	1.084	1.083
200° C	0.7%	0.5%	0.4%	1.2%	0.5%	0.3%
210	1.9	0.7	0.8	0.2	0.1	0.7
235	38.8	48.4	53.0	4.0	3.5	5.4
270	17.7	18.3	18.3	21.6	22.1	23.3
315	9.4	6.9	8.6	18.2	22.0	22.5
355	16.5	13.0	10.3	31.5	31.1	26.0
Residue	15.0	12.2	9.0	23.3	20.7	21.3
Sp. Gr. at 38/15.5						
235–315	1.034	1.034	1.038	1.039	1.038	1.039
315–355	1.106	1.110	1.114	1.125	1.114	1.118
Tar Acids by volume	1.2%	......	......	1.2%	1.3%	1.7%

CREOSOTE OIL WHICH RAN FROM CAVITY IN PILE No. 1
Two feet below Mud Line

Sp. Gr. at 38° C.	1.079
Water	1.0%
Distillation:	
210° C.	0.8%
235° C.	13.4%
270° C.	20.4%
315° C.	17.9%
355° C.	28.0%
Residue	19.5%
Sp. Gr. 38/15.5 of 235-315	1.045
Sp. Gr. 38/15.5 of 315-355	1.122
Acids by volume	2.8%

In view of the importance of obtaining further data as to the relation between impregnated piles and marine borers, investigations are now in progress, conducted by the San Francisco Bay Marine Piling Committee. A large number of test specimens are being exposed at a central point in San Francisco Bay, consisting of both treated and untreated pieces. Through the courtesy and with the coöperation of the San Francisco Bay Marine Piling Committee your Committee has inaugurated a series of similar exposures, consisting of round pieces of southern pine and Douglas fir impregnated with various special oils prepared for the use of the Committee through the courtesy of the Barrett Company.

In addition to these oils similar poles have been treated, among others with the following processes: Aczol process, Antimony Trichloride (on account of the high toxic character of this sale to lower organisms), a highly toxic wood tar preparation, etc., Full details as to these tests will not be available before the printing of this report, but it is anticipated that preliminary results with reference thereto will be available for next year's report.

Recent Literature: For those interested the following references are given pertaining to recent literature on this subject:

1. Report on Creosoted Piling Removed from Long Wharf, Oakland, Cal. (Proceedings of American Wood Preservers' Association, 1920, page 148.)

2. Report on San Francisco Bay Marine Piling Survey. (Proceedings of American Wood Preservers' Association, 1921, pp. 189-339.) Report of the outbreak of marine borers in San Francisco Bay, containing discussion of types of borers found on the Pacific Coast, biological conditions, salinities and temperatures of waters, nature of attacks, protective measures and service records. Illustrated.

3. First report of Committee of the British Institution of Civil Engineers appointed to investigate the Deterioration of Structures of Timber, Metal and Creosote exposed to the action of sea water. (London, 1920, pp. 1-301.) A very complete report dealing with timbers used in various parts of the world for use in marine construction, description of marine borers, protective measures, and detailed reports from engineers in

British possessions of their experience with marine protection. The report is illustrated with many plates and drawings.

4. Impragnering af Haventommer. A. Collstrop and Edv. Bülow. (Ingenioren, No. 11, 1919, Copenhagen, Denmark.) Inpregnation of Harbor Timbers, report by A. Collstrop and Edv. Bülow. (The Engineer, No. 11, 1919.) A general paper on piling protection with references to recent European and American investigations. The following recommendations are of special interest at this time:

1. "For pilings round timbers should be used exclusively, and other timbers should be of good sound wood without excessive specifications as to heartwood."

2. "Pilings and other timbers exposed to shipworms and marine borers are impregnated with tar oil (full cell treatment 180 kg. or more per cu. meter—11.2 lb. per cu. ft.). Other timbers are treated with tar oil according to Reuping method with absorption of 63 kg. (ultimately 80-90) per cu. meter. If timbers be green at time of impregnation treatment should be made subsequent to previous drying.

3. "In treatment coal tar oil is to be used with specific gravity of 1.04-1.1, preferably 1.075. It must distill as follows:

Up to 150 deg. C., not over 3 per cent
Up to 200 deg. C., not over 10 per cent
Up to 235 deg. C., not over 25 per cent

Proportion of tar acids about 6 to 10 per cent. Light tar oils are absolutely useless.

4. "All timbers are trimmed before treatment and heartwood must not be exposed.

5. "In structures impregnated timbers are to be used throughout; besides, care must be taken in repairs not to place green timbers along with impregnated timbers."

6. Om Palmaskens och Palkräftans Skadegörélse vid Skandinaviens Kuster. (Teknisk Tidskrift, June 25 and July 9, 1921, 15 figures.)

7. Holzzerstörende Krebse—F. Moll. (Naturwiss. Zeitschrift für Forst- u. Landwirtschaft, 13:178-207, 1915.) A complete description of species of Limnoria, Sphaeroma and Chelura, their structure, life history, distribution, habits and methods to be used to protect timber structures. Has a list of 140 titles of books and articles dating from 1723 to 1915.

8. Undersogelser vedrorende Paeleors og Paelekrebs Angreb ved Skandinaviens Kyster og Anvendte Forebyggelsesmidler. Report dealing with the attacks of Teredo and Limnoria on the coasts of Scandinavia together with description of protective measures used. A digest of information gathered by the section on roads, water and railroads of the Danish Engineering Society in co-operation with the Norwegian and Swedish Engineering Societies. (The report is printed in Ingenioren Nr. 41, 1921.)

This is an important report prepared by the Danish Engineering Society in co-operation with the Swedish and Norwegian Engineering Societies. The report summarizes information obtained as the result of an extensive questionnaire. It includes description of the life history of the Teredo and the Limnoria the influence of temperature and salinity, character of bottom, purity of water, currents, resistance to attack of piles driven at different times of the year, resistance of various kinds of wood, nature of attack, changes in violence of attack, seasonal variations, depth of water in relation to virulence of attack, etc., etc. There is also extensive discussion as to protective measures and it is of particular interest to note the reference to successful protection obtained where iron nails were driven into piles. One of the most interesting parts of the report consists of two maps on which the distribution of Teredo and Limnoria attack is given in great detail, with particular reference to extent or virulence of attack.

The Danish Committee established six grades, as follows:

(1) Where the marine borers have been traced in one or more places but where it cannot be said that the attacks are of much practical import.

(2) Where borers have been found here and there, but where attacks have done actual harm in only a few places.

(3) Where the borers are numerous enough to destroy a pile 25 centimeter (9 inches) in diameter in the course of a period of ten to twenty years so that the same must be replaced.

(4) Where such destruction occurs in the course of five to ten years.

(5) Where such destruction occurs in the course of two to five years.

(6) Where such destruction occurs in the course of one year.

The indications on the maps clearly show where Teredo or Limnoria is responsible.

Destruction of the sixth grade is particularly marked in the waters of Norway and Sweden at the entrance of the North Sea.

Future Work: Realizing the international character of marine borer activities, the National Research Council was appealed to for the purpose of formulating a broad program to coördinate the various investigative activities now being conducted and to stimulate additional research work. A preliminary committee has been appointed which has drawn up such an outline. It is hoped that those interested will contribute and coöperate with the Research Council to the end that this plan may represent the broadest possible viewpoint.

Your Committee strongly recommends that the A.R.E.A. continue to actively participate in the prosecution of the research work so necessary for a proper understanding of the habits of marine borers and methods for their control.

Recommendations: The result of examination of service records of piling on all coasts during the past few years leads your Committee to recommend that good creosoting will offer the best protection so far found. By good creosoting the Committee means a treatment conforming to the recommended practices of the A.R.E.A. both as to oil and treatment. We do not believe that there is sufficient knowledge as yet to warrant the use of special oils and that the A.R.E.A. No. 1 creosote oil should still be regarded as the standard for piling protection.

Appendix F

(5) PRESERVATIVE TREATMENT TO BE USED ON PILES AND TIMBERS IN LAND CONSTRUCTION

O. C. Steirmayer, *Chairman;* E. H. Bowser, H. A. Dixon, C. F. Ford, J. H. Waterman, *Sub-Committee.*

The very high cost of replacing piling and bridge timbers which have failed through decay or other causes, necessitating often the rebuilding of the entire bridge, brings forth considerations of chemical preservation of such material unlike that of any other treated wood used in railroad construction. First cost of the treated piling should be of secondary importance.

Zinc chloride and a combination of zinc chloride and creosote oil have been used to a limited extent as the preserving agent; however, your Committee is of the opinion that where the greatest degree of permanency is desired only creosote oil should be used in quantities which will insure thorough penetration in the treatable portions of each stick, and of such depth as will preclude the possibility of season checks extending beyond the line of treatment.

Your Committee recommends the following additions to the General Requirements:

Piling for Land Construction

Treatment shall be in accordance with specifications for preservative treatment of wood with creosote oil (full cell process). The net amount of oil left in the piling shall be not less than 15 pounds per cubic foot of wood.

Timbers in Land Construction

Treatment shall be in accordance with any of the following specifications:

1. Specification for preservative treatment of wood with creosote oil (full cell process).

2. Specification for preservative treatment of wood with creosote oil (empty cell process, with final vacuum).

3. Specification for preservative treatment of wood with creosote oil (empty cell process, with initial air and final vacuum).

The various processes of treatment shall be so manipulated as to reach a net retention of not less than 12 pounds of oil per cubic foot in all timbers, excepting bridge ties and guard rails in which the minimum amount may be not less than 8 pounds of oil per cubic foot of wood.

Failure of some creosoted structures in the past can be attributed to untreated surfaces exposed to decay when sawing off piles, framing, and boring of holes. Your Committee is of the opinion that instructions for field treatment of creosoted materials are very necessary and offers the following:

Instructions for Field Treatment for Creosoted Material

All treated timber and piling which is cut or bored after treatment shall have the surfaces so exposed covered with creosote oil. Where cut, the surfaces shall be painted thoroughly with creosote. Where holes are bored, they shall be poured full of creosote where possible.

Horizontal holes such as those for Sway Brace Bolts shall be filled by pouring creosote into them through a bent funnel.

The creosote shall be heated before using.

Where it is absolutely necessary to bore holes in piles to support scaffolding, or for other reasons, the holes shall not be left open but shall be poured full of creosote and a tight-fitting creosoted timber plug inserted.

Appendix G

(6) METHODS FOR STORING LUMBER AND PILING FOR AIR-SEASONING PRELIMINARY TO PRESERVATIVE TREATMENT

C. F. Ford, *Chairman;* R. S. Belcher, H. C. Bell, C. E. Gosline, J. K. Melton, J. H. Waterman, *Sub-Committee.*

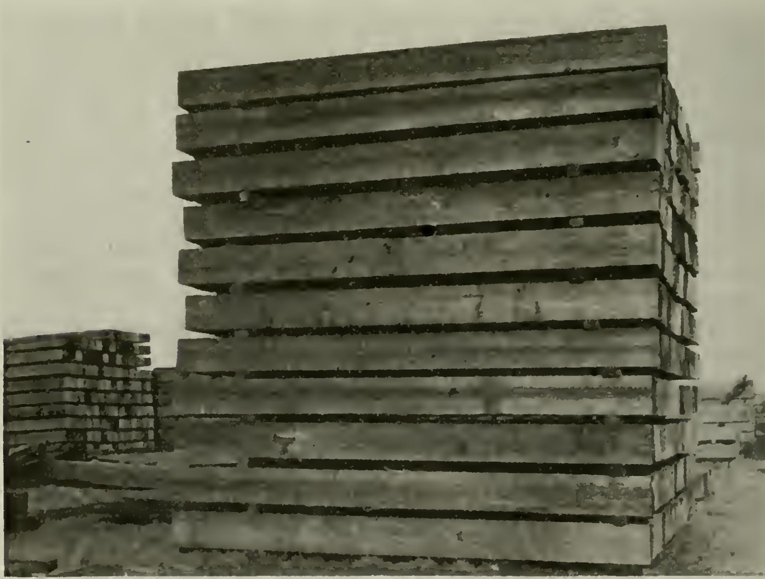
It is the opinion of your Committee that the top of the treated sills or stringers used for piling and lumber should be at least 12 inches above the ground instead of 6 inches, as now provided; and it is suggested that the Manual be revised to read as below, with the changes underscored:

"Material should not be treated until seasoned. If it arrives at the treating plant in a seasoned condition, ready to treat, it may be loaded directly from the cars to the trams; otherwise it shall be stacked: If ties, they should be stacked in layers of one or two and seven to ten, depending on the width of the ties, with alleys at least 3 feet width between rows of stacks extending between tracks, and at least 6 inches off the ground on treated sills; if lumber, it shall be segregated according to size and each layer in the pile shall be separated by at least 1-inch strips with an air space of 1 inch or more between each piece of lumber in any layer. For caps, stringers and other large timbers, 4-inch by 4-inch strips should be used to separate layers in piling, with alleys at least 3 feet wide between rows of stacks extending between tracks and at least 12 inches off the ground on treated sills; if piles, they shall be stored in a like manner, placing only one length in a pile, using strips 4 inches by 4 inches or saplings of equal size between each layer; reversing all sticks in every other layer in order to keep the pile level, with alleys at least 3 feet wide between rows of stacks and at least 12 inches off the ground on treated sills. The space under and between the rows of stacks at all times should be kept free of rotting wood, weeds, or rubbish. The yard to be so drained that no water can stand under the stacks or in their immediate vicinity."

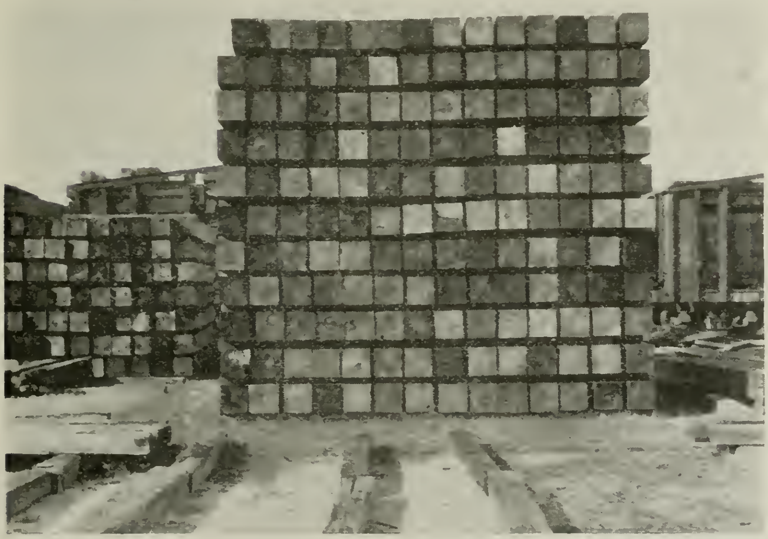
The following paragraph should be added as the next to the last paragraph, under General Requirements:

"In some localities, where weather conditions make it difficult to properly season piling or large timbers, it may be found desirable to locate the piles with ends to the East and West in order to secure direct rays of the sun on the ends of the sticks."

Proper Method for Storing Piling



Proper Method for Storing Short Dimension Lumber, Except That Twelve-Inch Sill Ties Should Be Used



PROPER METHOD FOR STORING LARGE DIMENSION LUMBER, EXCEPT THAT TWELVE-INCH SILL TIES SHOULD BE USED

REPORT OF COMMITTEE XII—RULES AND ORGANIZATION

W. C. Barrett, *Chairman;*
F. D. Anthony,
D. P. Beach,
H. L. Browne,
S. E. Coombs,
J. L. Downs,
H. H. Edgerton,
J. M. Fair,
R. H. Gaines,
E. H. Barnhart, *Vice-Chairman;*
R. H. Hallsted,
H. H. Harsh,
B. Herman,
E. F. Manson,
E. L. Martin,
R. N. Priest,
R. E. Warden,
A. A. Woods,

Committee.

To the American Railway Engineering Association:

Your Committee respectfully submits the following report on its activities during the year:

(1) Revision of the Manual

The Committee submits its report in Appendix "A." Its recommendation is given under the heading of Conclusions.

The Committee does not recommend any extensive revisions of the Manual this year, as it thought the members of the Association should have time to read and study the Committee's work as presented in the Manual just printed before any radical revisions were suggested.

The Committee does, however, present in Appendix "A," proposed revisions of the Manual in respect to duties of Signal Maintainers, in order to make such rules harmonize with the rules promulgated by the Signal Section, American Railway Association, and approved by that Association.

The Committee also presents in Appendix "A" rules covering the duties of employees engaged in the construction and maintenance of telegraph and telephone lines and appurtenances, below the rank of and including General Foreman, as prepared by the General Committee of the Telegraph and Telephone Section, American Railway Association. Inasmuch as these rules have not as yet been presented to the American Railway Association for approval, and in accordance with understanding your Committee had with the Special Committee of the Telegraph and Telephone Section, we submit these rules for information only this year.

(2) Rules for Conduct of Bridge and Building, Signal, and Telegraph and Telephone Work

The Committee submits its report in Appendix "B." Its recommendation is given under the heading of Conclusions.

The Committee recommends for adoption and printing in the Manual, rules for conduct of Signal Work, and presents for information only, the remainder of Appendix "B," covering rules for conduct of Bridge and Building Work.

The Committee is not ready to submit rules for conduct of Telegraph and Telephone Work this year.

(3) Use of Mechanical Appliances and Tools, and Organization of Labor Involved

The Committee submits its report in Appendix "C." Appendix "C" is presented for information only.

(4) Outline of Work for the Ensuing Year

1. Study the Manual and submit proposed revisions thereof. (Your Committee believes this subject will merit very intensive study and work next year.)

2. Complete, if possible, Rules for the Conduct of Bridges and Buildings, and Telegraph and Telephone Work, to be added to the "Manual of Rules for the Guidance of Employees of the Maintenance of Way Department."

3. Continue study of use of Mechanical Appliances and Tools, with organization of labor involved, in Maintenance of Way work, making, if possible, a final report.

4. Prepare list of names, terms and definitions, covering material, work and accounting involved in the operations of the Maintenance of Way Department. This to avoid the errors and confusion now caused by the use of so many different names, terms, etc., for the same material or the same work, by different foremen.

5. Recommend a carefully considered outline of work for the ensuing year.

CONCLUSIONS

1. The Committee recommends the adoption of that portion of Appendix "A" covering duties of Signal Maintainers, and that these rules be substituted for those now appearing in the Manual under the same heading.

2. The Committee recommends the adoption of that portion of Appendix "B" covering rules for conduct of work, Signals and Interlocking, to be added to the "Manual of Rules for the Guidance of Employees of the Maintenance of Way Department," and printed in the Manual.

Respectfully submitted,

THE COMMITTEE ON RULES AND ORGANIZATION,

W. C. BARRETT, *Chairman.*

Appendix A

SIGNAL MAINTAINERS

R. H. Gaines, *Chairman;* E. L. Martin, *Vice-Chairman;*
H. L. Browne, R. H. Hallsted,
R. E. Warden, *Sub-Committee.*

(Any rule preceded by a number in parenthesis is a rule of the Signal Section, American Railway Association, of that number.)

199	Signal Maintainers report to and receive instructions from the Supervisor of Signals.
200 (31)	Maintainers are responsible for the inspection, adjustment and proper maintenance of signal and other apparatus assigned to their care.
200A (32)	Maintainers must personally instruct their subordinates with a view to safety, efficiency and economy..
200B (33)	An assistant maintainer, in the absence of a maintainer, will consider himself in charge, unless a substitute has been provided. He must open all railroad mail addressed to the maintainer and perform all the latter's duties.
200C (34)	Maintainers must systematize their work, performing certain duties on certain days in orderly sequence, consulting the Supervisor of Signals as to the most efficient system to be followed.
201	They will have full charge of such forces as the Supervisor of Signals directs. They must see that these men properly perform their duties. They must keep the records and make the required reports of the time of their men, and of the receipt, distribution and use of the material furnished them.
201A (35)	Maintenance forces should have correct plans of all work under their care. These must be kept in good order and where they will be available when required.
201B (40)	Tool houses, block and interlocking stations, signal appliances, etc., must be kept clean and surroundings free from rubbish and weeds. Inflammable material must not be stored in, against or under buildings, unless provisions are made for safe storage of same.
201C (42)	All scrap and salvage material must be collected at headquarters and shipped in accordance with instructions.
201D (43)	All material must be stored in a place provided for that purpose.
201E (44)	Material delivered on the line must be neatly arranged and small parts properly secured from theft.
201F (45)	Housings, containing signal appliances, must be kept securely locked.
201G (46)	When inspecting an interlocking tower, check emergency tools, and if any are missing, see that they are immediately replaced and report to the Supervisor of Signals.

201H (48) Electrical measuring instruments must be handled with extreme care. Shipping instructions for damaged instruments will be furnished by the Supervisor of Signals on request.

201J (49) Employees must be on the alert to detect defects in maintenance, design, manufacture and installation of apparatus under their care. No chances should be taken with defective material, but it must be promptly replaced with material in perfect condition and full report made to the Supervisor of Signals in writing.

202 When any part of an interlocking plant is to undergo repairs, an understanding must be reached with the signal man on duty, in order to insure safe movement of trains and engines during repairs. If it is necessary to disconnect any switch, movable point frog or derail, it must be securely spiked in proper position before permitting trains or engines to pass over it.

203 Signal Maintainers must notify the Supervisor of Signals before taking any signal or interlocking apparatus out of service, and authority must be obtained, except in emergency, before such apparatus is taken out of service. Should an emergency arise which requires removal from service of any apparatus, signals must display their most restrictive indication; switches, movable point frogs and derails must be securely spiked in correct position and Supervisor of Signals, Division Engineer and Superintendent immediately notified by wire.

203A (50) In case of severe storm, maintainers should go to any points on their territory where they feel that trouble is likely to occur, keeping in touch with the telegraph office so that they will be available in case of trouble elsewhere.

203B (53) After a heavy wind storm, inspect pole line, signal blades, and other signal apparatus subject to damage.

203C (54) In case of severe electrical storm, make inspection as soon as storm ceases, and clear any cases of trouble by replacing or repairing damaged electrical apparatus.

203D (55) In case of snow or sleet storm, interlocking plants should be watched carefully to see that switches, pipe lines, etc., are kept clean and in operation, that the leverman observes rule requiring him to operate levers from time to time to keep them from freezing, and that sufficient forces are available to keep switches, etc., free from obstruction.

Remove snow and ice from signal blades, roundels and other movable parts where it might prevent proper operation or indication of apparatus.

204 In case of accident or serious damage to interlocking or signal apparatus in their territory, Signal Maintainers must immediately proceed to the place, asking for such assistance and material as may be required, and make repairs promptly.

204A (56) Failures should be given preference over all other work in the following order:

(a) False proceed signal indication.
(b) Highway crossing device failing to indicate approaching trains.

(c) False clear indicator indication.
(d) Electrical and mechanical locking devices failing to function so as to provide safety for the movement of trains.
(e) Single track automatic signals failing to assume a proceed indication.
(f) Interruptions at interlocking plants.
(g) Other failures.

204B (57) A thorough investigation must be made of every reported failure and the trouble must not be reported as due to a cause which is only suspected. In all cases endeavor to definitely determine the trouble and eliminate the true cause.

204C (58) In all cases of failure, damage, or other irregularities, a brief report must be forwarded promptly to the Supervisor of Signals, stating cause, nature and extent of damage and time repairs were completed. As soon as possible after repairs have been completed, Signal Maintainer must render report, Form ———, and forward same to the Supervisor of Signals with the least possible delay, retaining copy for reference.

204D (36) Temporary repairs or adjustments must not be made except when permanent work cannot be finished promptly. Permanent repairs or adjustments must be made as soon thereafter as possible.

205 (59) If an accident may have been caused, or is alleged to have been caused, by defects in the signal apparatus, a thorough examination must be made immediately of all parts involved, and telegraphic report sent at once to the Supervisor of Signals.

206 (63) Signal Maintenance employees must co-operate with track forces in joint track and signal work, to see that signal apparatus is maintained in proper condition.

207 Signal Maintainers shall make such inspection and repairs of signal apparatus under their charge as will secure proper operation. They must inspect the signal lights on their territories at regular intervals and make report to the Supervisor of Signals.

208 They must make the usual standard tests for condition and efficiency of interlocking switches, derails, etc., keep them adjusted and make the required reports.

REPORT OF SPECIAL COMMITTEE TELEGRAPH AND TELEPHONE SECTION AMERICAN RAILWAY ASSOCIATION; COVERING DUTIES OF EMPLOYEES BELOW AND INCLUDING GENERAL FOREMAN OF TELEGRAPH AND TELEPHONE.

General Foreman of Telegraph and Telephone.

The General Foreman of Telegraph and Telephone shall report to and receive instructions from the Superintendent of Telegraph and Telephone. He shall supervise the construction and maintenance of all telegraph and telephone pole lines, wires and their appurtenances and such equipment work as may be assigned to Telegraph and Telephone Maintainers—Section Linemen.

When a pole line is to be totally reconstructed or poles required to be moved, the location of such pole line, or of fixtures on bridges and structures must be agreed to by the Engineering Department.

He must make frequent inspection of all telegraph and telephone pole lines, wires, appurtenances and equipment under his charge and make the required reports.

He must know that Foremen, Maintainers and others under his supervision fully understand and properly perform their duties, keep account of and report their time in the manner prescribed and administer discipline when necessary.

He must know that Foremen and Maintainers are supplied with tools and materials necessary for the efficient performance of their duties and that they are properly used.

He shall keep himself informed in regard to all work being performed by contractors or others, who may not be under his supervision, which might affect the telegraph and telephone plant and report to the proper officer if the work is being done in such a way as to endanger the telegraph and telephone interests.

In case of storms, washouts, accidents or other occurrences causing prostration of the pole lines or otherwise affecting the circuits, he shall obtain full information of the extent of the damage, communicate promptly with the interested officials, assemble men and material where necessary and proceed to the point of interruption with the greatest haste possible to make the required repairs.

He must investigate failure or improper working of the plant and take action that will insure repairs being made promptly.

He must not make, or permit to be made, any alterations or additions to the plant without proper authority.

Assistant General Foremen, District Foremen, Supervisors of Lines and Inspectors of Outside Plant.

Assistant General Foremen, District Foremen, Supervisors of Lines and Inspectors of outside plant shall report to the General Foreman of Telegraph and Telephone. They shall be in charge of such forces and perform such duties as may be assigned to them by the General Foreman of Telegraph and Telephone.

Foremen Line Gangs.

The Foremen of Line Gangs shall report to and receive instructions from the Assistant General Foremen, District Foremen, or Supervisors of Lines as may be designated by the General Foreman.

They shall have charge of such forces as may be assigned to them. They must see that their men properly perform their assigned duties. They must keep the required records of the time of their men, and of the receipt, distribution and use of material supplied.

They shall have charge of and are responsible for such tools and materials as are necessary for the performance of their work and must know that they are properly used.

They shall obtain advance authority from their superior officer for any work involving the removal of any part of the plant that would interrupt the service.

Telegraph and Telephone Maintainers—Section Linemen.

Telegraph and Telephone Maintainers—Section Linemen—shall report to and receive their instructions from the Assistant General Foreman, District Foreman, or Supervisors of Lines as may be designated by the General Foreman. They shall also obey instructions issued by the Wire Chief in regard to clearing trouble and shall keep him advised of the work they are engaged upon and of their whereabouts at all times.

They are responsible for the safe condition and proper maintenance of pole lines, wires and the equipment as may be assigned to them and for the economical use of materials supplied them.

They must not permit any foreign wires or fixtures to be attached to telegraph or telephone poles, without the approval of their superior officer.

They must report to their superior officer anything contemplated or existing that may interfere with telegraph and telephone service or in any manner endanger persons or property, for example: new work of any character, track changes, power transmission lines within 500 feet of the railroad right-of-way, other paralleling lines, the poles of which would be within striking distance of the railroad right-of-way, new wire crossings, unsafe conditions in existing wire crossings, attachments of wires to buildings and other structures, etc.

They must keep an accurate pole diagram of the wires in their territory, and when changes affecting such diagrams are made, they shall advise the designated officer in order that the records may be kept complete and up-to-date.

They shall make inventory and work reports upon prescribed forms and forward promptly to the designated officer.

They must notify their superior officer before taking out of service any part of the wires or apparatus, and authority must be obtained, except in emergency, before such wires or apparatus are taken out of service. Should an emergency arise which requires the removal from service of any part of the wires or apparatus, the interested officer must be immediately notified by wire.

In case of accident, or serious damage to wires or apparatus, in their territory, they must immediately proceed to the point of interruption, requesting such assistance and materials as may be required, and make every effort to restore the circuits promptly in the order of their importance.

They must make such inspection, tests and repairs of plant in their territory and supply such reports as are required.

Appendix B

CONDUCT OF WORK

E. H. Barnhart, *Chairman;*
F. D. Anthony,
R. H. Hallsted,
A. A. Woods,
S. E. Coombs,
B. Herman, *Vice-Chairman;*
R. N. Priest,
D. P. Beach,
W. C. Barrett,
Sub-Committee.

SIGNALS AND INTERLOCKING

Track Circuits.

1. The track should be kept clean and ballast kept free from rails.

2. The track should be kept well drained, especially at road crossings and station platforms.

3. In case of rainstorm, weak track circuits should be tested and adjusted.

4. Bonding material should be kept intact.

5. Track connections and bootlegs should be kept at maximum distance below top of rail.

6. When track circuits are fed from storage or caustic soda battery, proper resistance must be maintained between the battery and the rail.

7. Cases where excessive amount of sand is used, or ash pans are cleaned on trunking or bootleg connections, should be reported.

8. Insulation in joints, switch rods and switch instruments should not be allowed to wear to deterioration.

9. Sufficient battery power should be maintained.

Line Circuits.

10. All wire joints in line should be perfect.

11. All cracked and defective insulators should be promptly replaced.

12. Dead wires on pole lines should be promptly removed and proper report made.

13. Proper slack wire should be provided in trunking at base of bootlegs.

14. Relays, locks, slots and motors must be closely observed at all times to insure that there are no mechanical defects.

Batteries.

15. Battery receptacles must be kept clean. They should not be exposed to extreme heat or cold.

16. Old battery solution should be buried on the right-of-way, in case there is danger that it will pollute streams or come in contact with pipes or wires.

Signal Mechanisms.

17. (82) Signal masts should be securely fastened to a sufficiently large and rigid foundation, and should be kept vertical.

18. (83) No other than signal wires or attachments may be placed on a signal mast.

19. (84) Ladders must be securely fastened to signal masts and bridges; bases of ladders must be secured to suitable foundations.

20. (85) Signal blades and numbers must be kept clean and well painted.

21. (86) Lenses and roundels must be kept clean and bright. Broken lenses and roundels must be replaced immediately.

22. (87) Lamp brackets must be so adjusted as to insure proper alignment of lamp with respect to spectacle and track.

23. (80) All foundations must be rigid, level and in good line.

24 Wire wheels for wire connected signals must be properly lined and run free in the frames.

25. (88) Cotter pins of the proper size must be in place in every hole provided for that purpose, must be in good condition and properly spread.

26. (89) Movable parts and threads must be kept clean and properly lubricated, but care must be used to avoid excessive lubrication.

27. (90) Signal apparatus should be painted as often as required to prevent deterioration. Paint must never be applied to the threads of screw jaws, adjustable screws, etc., but these should be kept properly lubricated. When painting pipe, care must be taken to see that the whole surface is covered.

28 (91) Gaskets for relay boxes and other housings must be in place and in good condition.

29. Motor brushes and commutators must be kept clean and in good condition and proper pressure on the brushes maintained.

30. Lightning arresters must be kept properly grounded.

31. Ventilation ports must be protected with wire mesh.

32. (78) Rubber covered wire must be protected from mechanical injury. Insulation must not be punctured for test purposes.

33. (77) As a permanent arrangement, joints must not be made in rubber covered wires underground or where they cross tracks.

34. (76) Avoid opening or short circuiting circuits, or taking any other action which may cause failure of signals or other apparatus with resultant train delays.

35 (79) Contacts of relays or other controlling devices must not be bridged. Relays must not be turned over, nor any other action taken which will endanger safety of trains.

36. (81) Standard clearances must be maintained.

Interlocking Plants.

37. (71) Except for the movement of trains, levers or other appliances of an interlocking plant should not be operated other than for inspection or test, and then only after a thorough understanding with the leverman.

38. In case of failure or damage which cannot be repaired immediately and which will endanger trains, signals must be secured to display their most restrictive indication until repairs have been made.

39. (68) Before removing rails, switch points or frogs, signals must be secured to display the most restrictive indication. The signals must not be restored to regular working order until it is known that the track is safe.

40. (73) The locking of an interlocking machine must not be changed nor removed from the machine.

41. (74) If the locking of an interlocking machine becomes disarranged or broken, signals affected must be set to display their most restrictive indication; switches, etc., in the route affected must be spiked and the Supervisor of Signals and Dispatcher notified.

42. (75) If necessary to discontinue the use of any interlocking signal, hand signals will be used, in accordance with the operating rules governing same. The Supervisor of Signals and Dispatcher must be notified immediately.

43. All route locking must be kept sealed or locked.

44. Facing point lock plungers must be kept so adjusted that they will clear the lock rod when unlocked, and must be perfectly square on the ends.

45. Time locks must be kept properly adjusted.

46. Circuit controllers must be kept properly adjusted.

47. Electric locks must be kept in good working order and contacts properly adjusted.

48. Shunt circuits must be maintained so that there are no breaks, leaks or undue resistance.

BRIDGES AND BUILDINGS

Bridges—Steel and Composite Structures.

1. Where foundations are doubtful, matter must be taken up for special instructions. Thorough investigation of the soil should be made to determine the kind of foundation to be adopted. If not feasible to carry masonry to solid footing, piling or other substructure should be used. Where pile foundation is to be used the Engineer will determine the number, arrangement and length of same. No permanent structure will be started until the foundations have been approved. Points for elevation and line will be given by the Engineer.

2. The bottom of all footing courses should extend below the frost line, be of sufficient depth to insure solid foundation and be thoroughly protected from all danger of scour and undermining.

3. Except in emergency, no structure shall be supported on false work until plan for same has been approved. The quality of timber, number and position of parts, length of spans, strength of stringers, bracing of bents, foundations of bents, blocking and wedges, size, spacing and bearing of

ties, must all be given careful consideration and safe limits not exceeded. Ties must not be left loose laterally on wooden stringers or girder flanges. When timber guards are removed, heavy nailing strips, strongly spiked to every tie, should be put on to prevent bunching of ties.

4. All bridge material should be handled so as to avoid injury and when stored should be placed on skids above the ground to keep it clean; girders and floor members placed upright to prevent the collection of water; heavier members placed below and the material arranged so as to be readily inspected and loaded.

5. Before assembling the metal work, all parts of the bridge which cannot be reached after erection, must be given two coats of standard paint.

This should include:

(a) The inner surfaces of pedestals and ends of stringers and floor beams.

(b) The ends of all web members and eyebar chords.

(c) So much of the riveted chords and end posts as may be necessary to clear web members and beams at or near panel points.

(d) The end intersections of all laterals, cross frames, etc.

6. In erection of truss bridges, the floor system should be lined and camber elevations given with instrument. Roller beds must be set with care to see that they are in proper position for the existing temperature, and square with the bridge. No straightening of the main members by heating will be allowed and any injury must be reported.

7. In riveted truss bridge erection, if lower chords line up properly on camber blocking, the splices in these chords shall be fully riveted before the spans are swung. Top chord splices and other main field connections shall generally be riveted after camber blocking has been removed and spans are swung with dead load only. When the parts are required to carry traffic, important connections, such as attachments of stringers and floor beams, shall have at least 50 per cent of the holes filled with bolts and 25 per cent with drift pins. When not carrying traffic, at least 33⅓ per cent of the holes shall have bolts. Rivets in splices of compression members shall not be driven until the members shall have been subjected to full dead load stresses. After swinging any span, it shall be immediately blocked to take all live loads. If lower chords do not line properly, they should not be riveted until after bridge is swung, and before swinging, at least three-fourths of the holes shall be filled with drift pins and bolts in the manner specified. Floor systems shall not be riveted until spans are swung. Laterals and cross frames must be fitted and bolted in place throughout entire span before any of their connecting rivets are driven. In stiff bottom chords of truss spans the center splices shall be driven first.

8. If false work is removed by accident or otherwise, before field riveting is completed, no live loads shall be permitted upon any span until at least 50 per cent of the holes are filled with bolts and 25 per cent

with drift pins. In case of stringers, resting on shelf angles, each shelf angle rivet may be considered equal to one drift pin and one bolt in the main connection or to one driven rivet.

9. When spans or floor systems must carry trains before riveting is completed, the speed of trains must not exceed 5 miles per hour and riveting must be completed as soon as possible.

10. Drift pinning shall be permitted only for the purpose of drawing parts together and not for making mis-matched holes come to a fit. All holes that do not coincide perfectly shall be reamed out.

11. The threads of bolts used in permanent field connections shall be checked so that nuts cannot turn after they are placed.

12. Eyebar heads shall be drawn together tightly and pin nuts must come on the pins equally at both ends. All members must be straight and true and not sprung to get them into place.

13. Rivets shall be driven tight. No recupping or caulking will be permitted. The heads shall be full and uniform in size and free from fins, concentric and in full contact with the metal.

14. Rivets shall be uniformly and thoroughly heated and no burnt rivets shall be driven. All defective rivets shall be promptly cut out and redriven. In removing rivets the surrounding metal shall not be injured; if necessary, the rivets shall be drilled out.

15. When renewals of decks of steel bridges or timber work of other steel structures are being made, the steel surfaces underneath timber shall be painted.

16. In dismantling old structures which can be used again, care must be exercised to avoid injury to the parts, particular attention being given to avoid bending eyebars, rods, connection plates and the outstanding legs of steel bridges. All old bridges intended for re-erection should be match marked before dismantling. Pilot and driving nuts must be used in erection and dismantling of pin connected bridges. All unpainted surfaces of old bridge material which is not immediately scrapped should be coated with standard paint.

Bridges—Wooden Structures.

1. Where records are not available, tests should be made on the soil to determine whether pile or frame bents are required. If piles are required, the length and kind should be determined.

2. A steam hammer is more desirable than a drop hammer for driving piles.

3. Piles should be driven to a firm bearing, but care should be exercised not to overdrive and damage the pile.

4. Where the character of the soil requires, the pile should be sharpened and fitted with a metal shoe. The head of the pile should be protected with an iron band or cap, if necessary.

5. Piles which are injured in driving or driven out of place, should either be pulled out or cut off and replaced with new piles.

6. Batter piles should be driven to the inclination shown by the plans, and shall require but slight bending before framing.

7. Butts of all piles should be sawed off to one plane, and the projections outside the cap trimmed or otherwise protected from the elements. If treated piles are used the cut surface should be protected with preservative.

8. Caps should have a uniform thickness and even bearing on the piles. The side with the most sap should be placed downward.

9. Pile or masonry foundations are preferable to subsills for frame structure, but when subsills are used, the bearing surface and thickness should be in proportion to the character of the soil and the loads to be carried.

10. Stringers should have a uniform thickness and even bearing on the bents.

11. Ties on open deck structures should be sized or framed to a uniform thickness over bearings and should be placed with the rough side upward. They should be spaced regularly, and cut to even length and line.

12. Timber guard rails on open deck structures should be laid to line and to a uniform top surface and firmly fastened to the ties.

13. Bulkheads should be of sufficient dimensions to keep the embankment clear of the caps, stringers and ties at the end bents of the trestle. There should be a space of not less than two inches between the back of the end bent and the face of the bulkhead. The projecting ends of the bulkhead should be sawed off to conform to the slope of the embankment, unless otherwise specified.

14. When replacing top portions of piles with posts, the old piles should be cut off where sound timber is found, if possible, below the surface of the ground. Good joint should be made between the old pile and the sill where entire bent is renewed, and between the old pile and post where a single pile is replaced. The sill or post should be securely fastened to the old pile. The posts should be drift bolted to the sill and where the joint is made below the surface of the ground, fill should be made and thoroughly tamped. Where conditions require, pile bents having one or more posts should be properly braced.

CONCRETE AND PIPE CULVERTS

1. No culvert shall be construced until its size has been determined by careful drainage survey. After drainage investigation has been completed the area of the opening shall be determined by taking into consideration size, shape and topography of drainage area, amount of rainfall, highwater records, and other data which may have bearing on area of opening required.

2. Record shall be kept of the height of water after heavy rains and of the behavior of bridges and culverts at such times.

3. Except where location, line and grade of culvert are such that foremen may be depended upon to properly lay out culvert, stakes for line and grade shall be given.

4. Before sand, stone or gravel is unloaded for concrete culverts, vegetation or rubbish should be removed from the place where it is to be unloaded, and, where necessary, means should be provided to keep the material from rolling down the embankment.

5. Excavation should be carried to sufficient depth to give necessary thickness of footing and to prevent danger of heaving from frost.

6. Excavated material should be placed in such position as not to interfere with the construction, and, if practicable, so that it may economically be used for back filling.

7. In case culvert replaces an existing structure, care should be taken not to excavate in such manner as to undermine piling, frame bents, footings, or other portion of such structure, without providing adequate means for its support.

8. Where possible, culverts should be located between the bents of trestle bridges. When it is necessary to remove one or more bents to permit construction of culvert, adequate provisions for the safety of the structure should be made. Foreman should be provided with plan showing the false work to be used.

9. In placing pipe culverts, excavation should be made for the bells of pipes, so that body of pipe will have a uniform bearing on the foundation. Filling material should be tamped around the pipe to the elevation of the middle of the pipe. In the case of concrete culverts, filling material should be tamped around the sides.

10. Pipes should be laid with the bell end up stream and to correct line and grade. Concrete head walls should be provided to prevent scour.

11. There should be at least twelve inches between bottom of tie and top of culvert. Vitrified pipes under road crossings should have not less than two feet of covering.

12. If possible, the work should be so planned as to avoid the construction of reinforced concrete culverts in cold weather, but if construction is necessary in cold weather, concrete aggregate and water should be heated before mixing. Concrete should have a temperature at the time it is placed and until set of not lower than 40° F. Proper temperature may be maintained with fires, salamanders, or other available means.

13. Concrete materials shall conform to standard specifications, and mixing shall be done so as to get concrete of proper density and plasticity. Concrete which has partly set shall not be used.

14. Forms should be of sufficient strength and so built as to prevent bulging and undue leakage of water.

15. Reinforcing bars shall be accurately spaced, securely held in position, and the concrete shall be thoroughly worked so as to completely embed them.

16. Parapet walls of concrete culverts should bear figures showing year in which culvert was constructed.

17. Where culverts are constructed on side hill locations, with outlet above bottom of fill, the fill should be protected with riprap, or with stone or concrete apron, as may appear advisable.

18. When necessary to extend concrete culvert, new and old work should be connected with dowels, the portions of the old culvert being stepped or cut away where necessary to make a good joint.

19. Filling material should be placed so that when embankment has settled, road bed will be of the standard width.

20. Where culverts replace trestles drift bolts through stringers into caps should be removed before filling is brought to such an elevation that it would interfere with the work. When stringers are removed, the space formerly occupied by them should be filled and track carried on the fill until embankment solidifies, when permanent ballast may be applied.

BUILDINGS

General—Maintenance.

1. Rubbish and inflammable material should not be allowed to accumulate in or around buildings or under platforms, and the spaces under buildings and platforms should be enclosed to prevent such deposit. Bird's nests, leaves, cinders, etc., should be removed from cornices, downspouts, gutters, etc., as soon as discovered.

2. Careful attention should be given to the maintenance of all portions of buildings not easily accessible, such as roof trusses, rods, cornices, under supports, gutters and downspouts.

3. Station platforms should be kept clean, free from rubbish, snow and ice, and defects repaired. They should be sloped to shed water.

4. Apparatus for extinguishing fires should be in place and in good working order at all times and should be protected against freezing.

5. Small defects, such as broken glass, locks, woodwork, etc., should receive prompt attention. Toilet facilities and sewer leads should be maintained in good order.

6. All heating appliances should be inspected in the Spring or early Summer so as to allow ample time to obtain repair parts and make necessary repairs, and all parts should be thoroughly tested after being repaired.

7. Ice houses should be placed in condition in time to receive the season's supply of ice.

New Work or Repairs—General.

8. New buildings or alterations to existing buildings should be constructed in accordance with the standard plans and specifications except where local building laws and regulations conflict. Before locating new buildings or platforms, or altering existing ones, consideration should be given to possible changes in alignment or grade of the tracks.

9. During the construction of new passenger stations and alteration of existing stations, special consideration should be given to the safety of pedestrians.

Foundation.

10. Before any foundation work is placed, special investigation should be made to determine the bearing power of the soil.

11. All pipe lines for water, sewer or drainage should be laid of sufficient depth to prevent freezing.

12. All ground connections for telegraph, telephone or electric circuits, and all wiring should conform to the underwriter's requirements.

Concrete.

13. Concrete mixed by machine gives a more uniform consistency than when mixed by hand.

14. Foundation concrete may be placed without forms, but neat work should be placed in substantial forms of approved type.

15. All anchors, bolts, ties, wood blocks, gratings and holes for pipe should be provided for in the forms.

16. Concrete should be handled from the point of mixing to point of deposit as quickly as possible. No concrete which has hard set shall be used. All reinforcing rods should be properly secured. Concrete should be thoroughly worked around the reinforcing material so as to completely embed same. To secure good bond on or against set concrete, the surface of the latter must be roughened, thoroughly cleaned of all foreign material and saturated with water.

17. In cold weather, concrete should have a temperature at the time it is placed and until hard set, of not lower than 40 degrees F.

18. Forms should not be removed until the concrete has attained sufficient strength to be self-supporting, and after the forms are removed, any small voids should be neatly filled with pointing of approved proportions. Exposed surfaces should be kept moist and protected from too rapid drying.

19. Where expansion joints are required, the bond between the two sections should be completely broken by the use of approved material and no reinforcement should extend across an expansion joint.

Brickwork.

20. All common and face brickwork should be laid even and true to line, plumb and level and with all joints accurately kept.

21. All brick courses should be proportioned so that they will work out evenly with the height of windows and doors and no split or fractional courses will be permitted.

22. The mortar should be thoroughly mixed of proper proportions and used at once. No mortar which has frozen or hard set should be used.

23. Centers, of approved type, should be provided for all openings. They should be well supported and rigidly braced, so as to properly carry the load until the brickwork has set.

24. All openings for pipes, anchors, bearing plates, ties, nailing blocks, etc., should be built into the brick walls accurately in the locations provided.

25. Brick flues, not provided with fire brick lining, should be provided with a terra cotta flue lining, and all joints in this lining should be completely filled with cement mortar. The fire hazard should be considered in the design and location of all flues.

26. Where new brick work joins old masonry or brick work, the surface of the old work should be roughened up, anchors provided and the work keyed so that there will be a proper bond between the new and the old work.

Carpentry and Millwork.

27. The sizes, grading and classification of all timbers and lumber should be in accordance with the standard plans and specifications. All kiln dried lumber should be protected from the weather.

28. All framing should be done to give close joints. All corners and angles should be solid and well braced.

29. All joints should be of the dimensions and spaced as shown on the plans. Avoid leveling joists on wooden blocks or chips. Headers and trimmers should be of sufficient strength to carry the load.

30. Roofs should be accurately fitted and securely fastened. Chords of trusses should be preferably of one piece and should be set level, plumb and securely braced longitudinally and in the planes of the top chords. Trusses should be framed with the proper camber. Rafters and purlins should be set at the centers required. They should have a solid bearing over the wall plates, beams, etc., and be securely fastened at all points. Sheathing should be of uniform width, securely fastened at every bearing and join on the rafters.

31. Siding should be placed truly horizontal with tight square butt joints, closely and accurately fitted against all casings, sills, etc.

32. Flooring should be evenly laid in long lengths, securely fastened and join on the joists. All flooring should be tightly driven up before fastening, so that joints are tight.

33. Window and door frames should be substantially built, and should be securely framed into the sills and heads. They should be set plumb and true, braced, protected and securely anchored into the masonry. Frames should be of the proper size to receive sash and doors and be weather proof.

34. Stairs should be strongly and rigidly built. Outside steps should be framed with proper waterfall.

35. All exterior and interior trim and finish should be free from hammer marks and neatly and accurately fitted. Brackets for overhang-

ing roofs should be set true against solid bearings and securely fastened to the walls.

36. Sash should be accurately made to fill the openings, dressed and sanded to a smooth finish, and should be properly hung, hinged or pivoted. Double hung windows should have sash carefully balanced and counter weighted. Sash should be fitted to operate easily, but not be so loose as to rattle.

37. Doors should be properly and neatly hung, so as to fill the openings. Sliding doors should have suitable protection when open and should be so hung as to prevent lifting off the track from the outside. Fire doors should be so hung as to close automatically in accordance with the standard practice of the fire underwriters. Double acting doors should be hung to swing clear and should fill the openings.

38. To make roofs watertight thoroughness in fitting of flashings and work around openings is of vital importance.

39. Guarantees of ready prepared roofing should not be relied upon to secure proper results. A record should be kept showing full information as to date and by whom placed, manufacturer, brand, guarantee, etc. Inspections to ascertain if the roofing is giving service in accordance with the guarantee should be made at intervals.

40. When practicable, downspouts should be placed outside the buildings and if so placed should be properly protected against damage.

Plastering.

41. Green lath should not be used. Before plastering is applied, lath should be moistened to prevent plastering from cracking.

42. Lath should be securely fastened at every bearing and no lath should extend beyond any corner or angle.

43. In winter, proper temperature should be maintained to prevent plaster freezing. Lime and cement should be stored in a dry place until used.

Plumbing, Heating and Lighting.

44. All plumbing must meet requirements of local regulations. All piping should be so located as to be easily accessible.

45. Heating plants should be of sufficient capacity. Radiators for steam and hot water plants should be so placed as to interfere as little as possible with the best use of space.

46. Lights should be so placed as to give the maximum efficiency.

Painting.

1. Before paint is applied, the surface must be cleaned of all dirt, grease, oil, rosin, scales, blisters and loose paint which does not adhere firmly.

2. On old structures, the first coat of paint should be applied as soon as possible after cleaning. Large structures should be cleaned and painted in sections.

3. In all cases, the cleaning of a structure and applying the first coat of paint should be carried on under rigid supervision.

4. No painting is to be done during wet or freezing weather, or when the surface of the wood or metal is not perfectly dry.

5. Paint must be thoroughly mixed before it is removed from the container.

6. Paint must be worked out well in order to give an even coating, must dry out with a uniform gloss, must be uniform in color and of sufficient thickness to protect the material.

7. Each coat of paint must be allowed to thoroughly dry before applying another coat and each coat must entirely cover previous coats.

8. Where special paint or other protection is desirable, the proper authorities should be advised and authority requested for its use.

9. When painting steel structures, the date, kind of paint and number of coats applied should be stenciled in plain characters on one or more members where the characters can be easily seen.

10. On new steel structures, the first field coat should have a different tint from the first shop coat and the second field coat from the first field coat.

11. All exposed structural steel in new bridges, buildings, etc., shall receive a full priming coat and at least two field coats of approved paint.

12. At least once each year, all exposed structural steel should be carefully examined and all signs of scaling paint and rust removed and the cleaned portion given the same treatment as new work.

13. All steel structures exposed to brine, engine gases, etc., must receive frequent and careful inspection and be cleaned and painted or oiled when necessary to protect the steel from corrosion.

14. All unpainted surfaces of old steel structures which are not to be scrapped immediately should be painted when the structure is dismantled.

15. All buildings should be kept neatly painted.

16. When painting buildings, the date should be stenciled in plain characters on one or more places on the building where the characters can be easily found.

17. All old buildings should be repaired before they are repainted.

18. New work is to be primed and have one or more coats of color.

19. New buildings must have all knots and pitch streaks covered with thin shellac before priming. After being primed all punched nail holes should be stopped with putty.

20. When old buildings have been patched with new woodwork, these new parts must be primed separately, and allowed to dry before a full surface coat is applied.

21. Repaired parts of painted woodwork must be painted as soon as practicable after repairs are made.

22. All private buildings erected on the right of way of the railroad must be painted with a standard color.

Shop and Terminal Buildings and Structures.

Deferred until next year due to lack of time for proper consideration this year.

Water Service.

Deferred until next year due to lack of time for proper consideration this year.

Appendix C

USE OF MECHANICAL APPLIANCES AND TOOLS, WITH ORGANIZATION OF LABOR INVOLVED

H. H. HARSH, *Chairman;*
J. M. FAIR, *Vice-Chairman;*
E. F. MANSON,
J. L. DOWNS,
E. L. MARTIN,
H. H. EDGERTON,
Sub-Committee.

General Organization

The Sub-Committee recommends the following organization for handling and care of the work equipment of a railroad. At the head of this organization there should be a:

Supervisor of Work Equipment, reporting to the Chief Engineer, or to the Chief Engineer of Maintenance, depending upon the road's organization. This officer's duties include the following:

He has charge of all work equipment including—

Hoists or clam shells, in the yards, at the round house or out on line.
Hoists in the store department.
Steam shovels.
Ditchers.
Speaders.
Motor cars.
Weed mowers.
Tie tampers.
Rail layers.
Portable rail saws.
Etc.

He arranges for systematic inspection of equipment.

Instructs operators in charge of equipment.

Has charge of all equipment inspectors.

Has general supervision over district or division repairmen on special equipment.

Arranges for distribution of equipment and transfer of equipment when so directed by his superior officer.

He has charge of repair shops where machines are repaired if there is sufficient work to justify one shop, otherwise he instructs and directs shop superintendent as to nature and amount of repairs to be done.

EMPLOYEES

Engineers on hoists and every one above the rank of laborer on all steam work equipment are employed by the Supervisor of Work Equipment and then are turned over to the division forces. But, they must be satisfactory to the division men to whom they report.

To the Supervisor of Work Equipment they are responsible only for care of the machine they are in charge of. These men are considered "system men" and they go where the machine goes and keep the same machine.

Organization of Outfits

Steam Shovels

Equipment moved over the system as a unit.

Shovel.
Bunk Car.
Tool Car.
Dump Cars.

Crew:

Engineer, Craneman, Fireman, Watchman } Employed by Supervisor of Work Equipment. Carried on Division Payroll.

Ditchers: Each one is considered as a complete unit and moved together over the system. It consists of:

Ditcher.
Flat car.
Dump car.
Bunk car.
Spreader.
Clam shell attachment.

Crew:

Engineer, Fireman } Employed as wanted through the Supervisor of Work Equipment.

Labor: Is employed by the division where machine is in operation.

Locomotive Crane:

Crane.
Bunk car.
Boom car.

Crew:

Engineer, Fireman } Employed as wanted by Supervisor of Work Equipment.

Spreader:

One Operator. Employed as wanted by Supervisor of Work Equipment.

Portable Rail Saw

(Made at Industrial Iron Works, Bay City, Mich.)

Mounted on a car and moved over the system. Has no power of its own. Uses a locomotive to furnish steam. Takes a day to dismantle and three days to set up. The side rods are taken off the locomotive and it is then blocked to the track and is used as a stationary boiler.

Crew:

Foreman Engineer Craneman Fireman	Employed by Supervisor of Work Equipment and carry on Division payroll.

Laborers, employed by the Division, 2 drillers, 2 chippers, 2 on car old rail is on; 2 air hoists; 5 tablemen; 2 loaders; 3 on the ground at odd jobs.

Largest output 376 rails complete in 8 hours, drilled, chipped, and loaded on cars. Average daily run during the year, 366 rails.

System of Repairs

INSPECTED

Repair parts ordered and sent to where repairs are to be made.

Work list is made out showing what is to be done.

Engineer of the machine is sent to the shop where the repairs are made and oversees the work done.

Distribution of Machines

The distribution for the season is fixed by the Supervisor of Work Equipment in conference with the Chief Engineer or Chief Engineer of Maintenance of Way, or whoever decides for the whole system what the outline of the season's expenditures is going to be.

Points to consider:

Men who operate the machines should be so assigned as to be nearest their homes.

New machines should be put on the hardest work. If rock work be governed accordingly.

Sources of water and fuel for the machines come in for thorough consideration.

The individuality of the men is better adapted to some locations than to others. A little powder work of blasting can be done by some men and not by others.

Division Repair Shops

These are used for motor cars only—division repair shops under the control of the Division Engineer; but they can also be used to repair track mowers and other small maintenance of way equipment.

Motor Cars

DISTRICT INSPECTOR.—One to about 4,000 miles—700 cars. Reports to Engineer of Maintenance of Way of the District. Looks after motor cars and tie tampers.

DIVISION INSPECTORS.—One or two motor car inspectors to each division, 30 to 40 cars to each inspector. Reports to Division Engineer.

Each has a standard list of parts, and keeps in stock one or two extra power-plants, motor engines for the cars.

Travels on a motor car of his own, and carries an outfit of tools, and small repair parts.

He makes minor repairs and adjustments in the field and instructs the foremen in the care and operation of the cars. If he finds a bad power plant on a car, too bad to be repaired on the ground, he sends in for his extra engine and when it arrives installs it.

Does not handle steam shovels or water service.

Reports on Motor Cars

Each car the Inspector inspects and repairs he reports on and the report is signed by the Foreman, to whom car is assigned.

This gives the Supervisor information on what their foremen are doing to keep up their cars.

R.R. SYSTEM ______________ FORM "A"

MOTOR CAR OPERATORS MONTHLY REPORT.

MAKE OF ENGINE ______ AGE ____ YRS MAKERS NO. ______ R.R. NO. ______

KIND OF BODY (FACTORY OR SHOP MADE, OR HAND CAR) ______________

SECTION NO. ____________ DIVISION ____________ MONTH OF ________ 19____

DAY OF MONTH	GASOLINE	LUBRIC'G OIL	CUP GREASE	NO. OF DRY CELLS USED	MILES RUN TODAY	LOAD		HOURS OUT OF SERVICE ON ACCOUNT OF REPAIRS	HOURS SPENT REPAIRING CAR "9"	REPAIR PARTS		COST OF REPAIR PARTS
						NO. OF MEN	NO. LBS. ON TRAILER			KIND	MAKERS NUMBER	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
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×MARK UP AMOUNTS PUT IN CAR ON DATES USED. — — NO. OF MILES PER GALLON OF GASOLINE THIS MONTH ________. AVG. NO. OF MEN HAULED PER DAY ________ TRAILER USED ________ DAYS. — IN COLUMN "9" SHOW "WORKING HOURS" ONLY THAT CAR IS OUT OF SERVICE ON ACCOUNT OF REPAIRS. IF CAR IS SENT TO SHOP, MARK ON DATE "SENT TO SHOP" AND ON DATE RETURNED, AND DESCRIBE REPAIRS. COLUMN "9" TO BE FILLED IN BY SUPERVISOR.

OPERATOR ______________ POSITION ______________

R. R. System ______________________________ Form "B"

Supervisor's Monthly Motor Car Report.

______________________ Supervisor ______________ Division. Month __________ 19___

Sec No	Motor Car			Gallons		Lbs Cup or Used	No Dry Cell	Cost of Operating Car					Mileage of Car	Cost per Mile Run	Aver Load Men	Trailer Used Days	Miles per Gallon Gas	Days Car out of Use
	Maker	AE	No	Gas	Oil			Fuel	Cells	Material	Labor	Total						

Performance of Cars Grouped as to Different Makes.

Make	No. of Cars	Aver of Car	Gallons		Lbs Cup Grease	No. Dry Cell	Cost of Operating Car.					Mileage of Car	Cost per Mile Run	Aver Load of Men	Trailer Used Days	Days Car out of Use
			Gas	Oil			Oil	Dry Cells	Material	Labor	Total					

Note:— In columns "Material" and "Labor," show cost of work done in shop together with cost of repair parts and labor repairing, as reported by operator of car.

______________________________ Supervisor.

R. R. SYSTEM____________________ FORM "C"

— PERFORMANCE OF MOTOR CAR —

__________ DIVISION __________ MONTH OF __________ 19__

MAKE OF CAR	NO OF CARS	AVERAGE AGE	TOTAL MILEAGE OF CARS	TOTAL GALS OF GAS USED	MILES RUN PER GALLON	TOTAL COST OF OPERATING	AVER. COST OF OPERATING PER MILE	AVERAGE LOAD MEN	TRAILER USED DAYS

NOTE:— INFORMATION FOR THIS REPORT TO BE OBTAINED FROM SUPERVISORS REPORTS, FORM "B" THIS FORM TO BE SENT TO CHIEF ENGINEER, MAINTENANCE OF WAY EACH MONTH, TOGETHER WITH A COPY OF EACH SUPERVISORS REPORT FORM "B."

____
DIVISION ENGINEER.

SPECIAL MACHINES AND COMBINATIONS

Ballast Handling Equipment

TIE PLOW.—The tie plow used in the spreading of ballast which has been dumped on track by center dump cars, is a device made from a 9-foot tie and old angle bars, to the dimensions shown in Fig. 1.

The total cost of plow is:

Material	$12.61
Labor	1.78
Total	$14.39

In operation the plow is placed under the front of the front car with the wrought iron bars resting on the ball of the rail. Ties are placed on top of plow and wedged into position under drawbar of car. Car is pushed with plow in front through ballast which has been unloaded, pushing out ballast from between the rails. This throws out all ballast to within one inch of the surface of the ties. Remaining ballast is then forked out from between the rails.

In usual cases the plow is applied and operated by the section gang on whose section the ballast is being unloaded, although the plow can be handled by Foreman and two men. While in motion the plow is watched and signals passed to enginemen on work train.

The accompanying photographs show plow in operation with gang of Foreman and nine men. Four cars of rock ballast were unloaded and spread in 20 minutes, 10 minutes being used in each operation or at a cost under present scale of wages of $.0077 per cubic yard for unloading and $.0077 for spreading. By using this type of plow, from 75% to 80% of the ballast is plowed out from between the rails; the remainder must be cleaned out by hand.

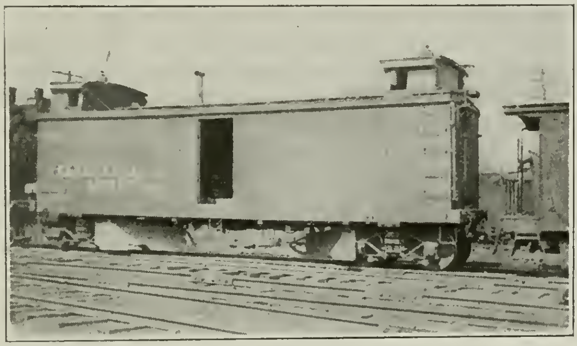
Snow Flanger Used for Ballast Plow

After ballast has been dumped on track by center dump cars and leveled to the top of rail by using tie in front of rear truck of ballast car, it can be thrown from between the rails by use of snow flanger. Snow flanger consists of a box car with two plows hung between the trucks in such a manner that one plow will operate in each direction. The plow is pushed by the rear truck and suspended from the body of the car in such a manner as to permit it to be raised or lowered by air. The lowest position of plow is 5″ below top of rail and highest position 4″ above top of rail. In using snow flanger as ballast plow the blades of plow should be strengthened by application of heavier plates.

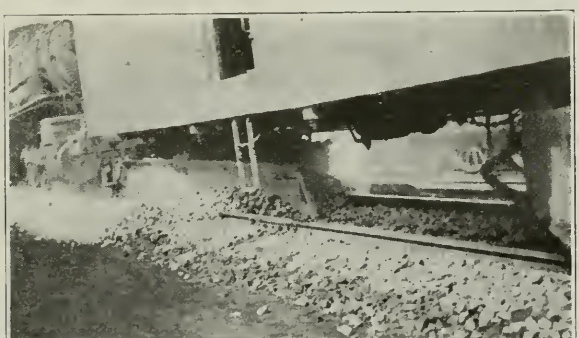
In operation the flanger which is carried in the ballast train is pushed over the track through the ballast which has been dumped, leveling the ballast to approximately one inch above the top of ties. The ballast remaining between the rails is then cleaned out to proper depth by hand. Approximately 75% of the ballast is taken out by the flanger; the remaining 25% must be removed by hand.

The organization used in handling of flanger consists of work train crew, one man to operate levers, raise and lower plow, and one man to watch plow and signal operator and engineman. The work of leveling by flanger of four cars of ballast requires approximately 10 minutes.

The use of snow flanger as ballast spreader appears to be no more efficient than the use of tie plow and unless equipment is standing idle should not be considered on account of the expense involved in the equipment.



Snow Flanger Used as Ballast Plow in Use on the Pennsylvania.



Plowing Out Ballast with Snow Flanger.

Lidgerwood Unloader for Gravel Ballast

The most economical method of unloading train loads of gravel ballast in side door cars is to use Lidgerwood unloader with plow.

This apparatus consists of a plow, of slightly less width than the inside width of the cars, a cable which can be purchased in length for 10, 20, 30, 40, etc., car lengths, and the Lidgerwood. This latter is a power driven drum upon which the cable is reeled.

In operation the cable is stretched over the cars from the Lidgerwood to the plow, the plow being placed at the rear of the train. The cable is usually stretched by hand, although where a number of trains are to be unloaded a boom is erected to assist in stretching cable. The train is then run to location at which gravel is to be unloaded. The doors are opened and with the train in motion the Lidgerwood drum reels in the cable pulling the plow through the cars plowing off the gravel. The plow is left standing in the ballast car next to the Lidgerwood. The doors of cars should be closed before leaving the work.

The organization used is work train and crew, one foreman and 10 to 14 laborers, depending on the length of cable to be used. While Lidgerwood is in operation one man passes signals to operator of Lidgerwood and to engineman to control the amount of ballast unloaded. The plow is followed through the train by the gang, which cleans up cars and prepare to close doors.

In a recent test of cost of unloading 40 cars of gravel from Haskell-Barker cars, 1 foreman and 14 men performed as follows:

Stretch Cable	40	minutes	
Open Doors	30	"	
Plow Off Ballast.........	25	"	
Close Doors	40	"	
Total	135	"	(2 hrs. 15 min.)

Rate of Foreman $.54 per hour, Labor $.39½ per hour. Total cost $13.66. Total cu. yds. 1200. Cost per cu. yd. $0.0114.

Pneumatic Tie Tampers

There is no part of track maintenance which has required more labor in the past than that of surfacing of track. The production of mechanical means of tamping of ties has been the aim of a number of manufacturers.

In the last seven years considerable progress has been made in the development of pneumatic tampers. The results obtained by tests run on efficiency of these machines have proved their economy over the old method of hand tamping.

The experience of the roads who have used this machine considerably indicates that the machines are a success and that it is a matter of education and organization to secure favorable results. There appears to be three factors which should be considered for their successful operation:

(a) Mechanic familiar with a machine to supervise its operation and to educate the section foreman and machine operator.

(b) Foreman and laborers should be educated as to the proper method of tamping and as to the time that each tie should be tamped.

(c) A general overhauling of the machines at the end of the seasons so as to have them in first class condition for the following season. This to eliminate repairs, barring accident, during the season of surfacing.

In order to secure the full efficiency of the machines it is desirable that some type of report be furnished daily by the foreman operating the machine. This report should in general show the hours worked, the cost of the gang, ties tamped, quantity and cost of oil, gasoline and grease, character of work, loss of time, and cost of repairs. From this information, data can be accumulated by the Division Engineer's office which can be used in increasing the efficiency of the machine if they have fallen below the standard for that type of machine.

The results which have been obtained by several of the railroads who have used the pneumatic tampers for several years justifies more extensive use of tampers. The following statement shows the cost in money per tie tamped which was secured by tests on the D. L. & W., B. & O., and I. C.:

COST PER TIE TAMPED

D. L. & W.	$0.113	8 weeks special test
D. L. & W.	0.15	2 machine season
B. & O.	0.166	20 machine season
I. C.	0.092	1 week special test
L. V.	0.136	

All rock ballast. The variation in rate per hour paid the laborer will explain most of the variation in figures on the Illinois Central and Delaware, Lackawanna & Western.

In the handling of four tamper outfit the following organization is usually used:

Foreman.
Operator of Compressor.
Four laborers operating tampers.

The foreman's time is divided between the tamping machine and the supervision of the remainder of the gang who are used in throwing ballast, dressing and spacing of ties. The operator is usually one of the men of the gang who spends a small portion of his time in care of the machine, this being approximately 1 hour 30 minutes per 8-hr. day, remainder of his time is spent with the gang, in dressing. The four laborers tamping usually work 6 hours in the 8 hour period, the remainder of the time is spent working with the gang, in lining and finishing of surface.

Machines should be detailed to the Division by the General Officers, being under the direct supervision of Division Officer who reports to the Division Engineer. Repairs and maintenance to machines should be handled by the same organization handling repairs to motor cars.

Pneumatic Tampers

Operated by 4 cycle—30 H. P. Air Compressor. Manufactured by Taylor Engineering Company, Allentown, Pa.
July, 1921, near Scottsville, W. of Meshoppen, Pa.

Force: 1 Foreman.
8 Laborers, operate 8 guns.
2 Laborers, shovel in ballast, operate jacks.
1 Laborer, operates air compressor.

Total... 1 Foreman, 11 men.

Raised and tamped 9,000 ft. track.

Compressor worked 21 days: Idle 4 Sundays, 1 holiday.
2 days lining track.
2 days men off job laying rail.

Cost:

Labor	$645.87	
Oil and Gas.........	84.13	(used 353 gal. Gas at 21c)
Maint.	.00	
Total	$730.00	or $.081 per lin. ft.

Track Mowers

These machines are successful as long as the operator understands that they must be regulated according to the kind of weeds to be cut. The experience of the different roads with these machines has varied considerably and it is not possible to give a definite opinion as to their operation.

One railroad has found that it is hard to keep the speed down and therefore had discarded gasoline and substituted a mule. They now haul their track mowers along by horse power or mule power at 2½ miles per hour and get along very nicely.

Another road has found that if it is run at a high rate of speed, four miles per hour, it will cut the tougher stuff such as heavy sweet clover and hemp and that it takes a high speed to accomplish any results with this tough stuff but at the same time going at a high speed it will not cut quack grass or the ordinary grasses. This road is in favor of using two lengths of cutter bar, one to get the grass far out and another to trim up close in. Also they have adopted a wrinkle which while it may not be new is ingenious in saving. They take out two of the bolts and substitute wooden pins for them and then when the cutter bar accidentally hits an old rail rest or a rail itself the pins will break out and the bar be saved.

One machine will cover about ten times as much as a man.

Bonding Machines

There are several styles of pneumatic bonding machines any one of which will do about twice as much work as hand labor.

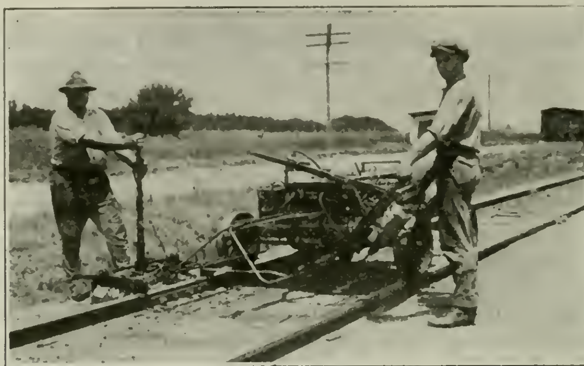
The M. K. & T. Railway have developed an electric bonding machine which was used on some recent signal construction work. The machine, which consists of a storage battery and two drill frames, is supported and carried on a light safety first type motor car. The battery, which is assembled in two trays with slip electrical connections, is carried on each side of the car, while the two drill frames are suspended ahead of the car on a light steel framework, all of which is easily disconnected, and removed from the car. Each drill frame carries two Black & Decker 32-volt electric drills which are operated in multiple and so arranged that two holes required for each wire are drilled simultaneously. Each frame weighs 115 lbs., while each tray of the battery weighs approximately 150 lbs. The drills are high speed and high speed steel bits are used with the results that it requires only thirty seconds actual drilling time to drill a joint, so that in actual work one signal man and two helpers have accomplished practically the same amount of drilling and bonding in a day that was formerly done by a foreman and six men with hand machines.

Cost of Bonding Track by Hand Drilling

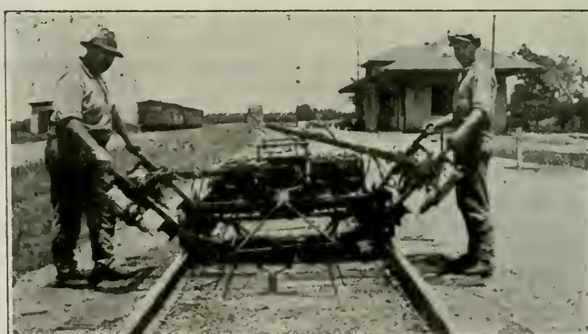
1 Foreman		$ 7.20
6 Helpers	at 4.72	28.32
640 Bond wires	at 2.86 C	18.30
640 Channel pins	at 15.00 M	9.60
6 Drill bits broken	at .60	3.60
1 Drill bit worn out	at .60	.60
Total cost per mile (320 joints)		$67.62
Cost per rail joint		.2113

Cost of Bonding Track With Electric Power Drill

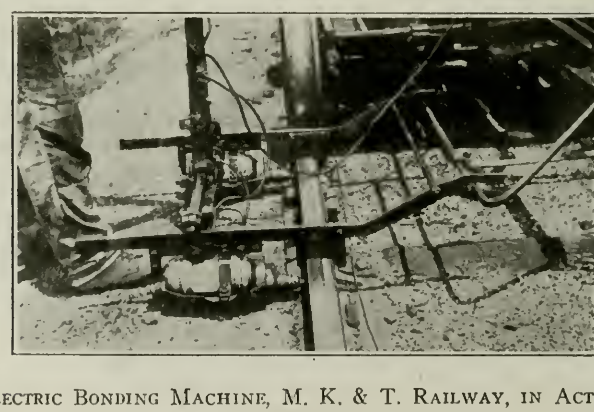
1 Foreman		$ 7.20
2 Helpers	at 4.72	9.44
600 Bond wires	at 2.86 C	17.16
600 Channel pins	at 15.00 M	9.00
1 Drill bit worn out	at .60	.60
2 Gallons gasoline	at .20	.40
½ Gallon oil	at 1.00 gal.	.50
Total cost per 300 joints		$44.30
Cost per joint		.1443
Total cost per mile (320 joints)		46.18



Electric Bonding Machine, M. K. & T. Railway.



Electric Bonding Machine, M. K. & T. Railway, Unfolding.



Electric Bonding Machine, M. K. & T. Railway, in Action.

Rail Handling Machines

(a) Loading and Unloading

Air Unloader: The machine in general use for handling rail in and out of cars. Consists of an "A" frame with boom, and is placed on a standard flat car. An air piston with a 5-foot stroke furnishes the power and the cable is wound so that a 15-foot lift is obtained. A work train is necessary and air for the cylinder is taken from the train line. The boom is swung by ropes, leading from the end of the boom to the ground.

The following organization is generally used:

Loading and Unloading:

1 Foreman.
1 Machine Operator.
1 Tongman in car.
1 Tongman on ground.
1 Railman in car guiding rail.
1 Railman on ground guiding rail.
2 Ropemen, one working on each side to pull boom.

This machine requires no engineer, or fireman, as on a steam ditcher, locomotive crane or derrick car. It is always carried on the work train and used for loading and unloading of miscellaneous materials as well as rail.

In congested territory, two air loaders are installed on one flat car, one on each end, with the same organization for each as outlined above, except that only one Foreman is used. The advantages of this method are in speeding up the work and the use of only one work train.

(b) Laying

1. Locomotive Crane—The Lehigh Valley Railroad used two locomotive cranes in relaying 136-lb. rail on main track during June, 1921. The track was abandoned during the operation and all traffic was handled over the other main, using a work train engine as pilot. Each crane handled the rail on one side only, and the following organization was used on each:

	North Rail Loco. Crane No. 95556		*South Rail Loco. Crane No. 95564*	
	Foremen	*Men*	*Foremen*	*Men*
Pulling spikes ahead of crane	2	28	3	30
Throwing out old rail	1	10	1	8
Adzing	1	7	1	8
Removing old and laying new tie plates	1	4	1	5
Laying new rail with crane	1	9	1	10
Applying new joints and full bolting	5	35	4	36
Gauging new rail	2	16	1	15
Full spiking new rail	4	37	4	49
Applying rail anchors	1	9	1	9
Removing and replacing road crossing	1	9	..	..
Loco. crane crew, Engineer	..	1	..	1
Loco. crane crew, Fireman	..	1	..	1
Total	19	166	17	172

First rail laid	8:15 a. m.	7:42 a. m.
Last rail laid	4:30 p. m.	3:17 p. m.
Total number of 136-lb. rails laid	490	647
Track closed fully bolted and spiked	5:30 p. m.	5:00 p. m.

Bonding organization using one tie tamper with 8 pneumatic drilling machines:

2 gas engine men.
8 signalmen handling drills.
4 men bonding.
2 men sharpening drills.
2 men distributing material.
3 men replacing boot-leg wires.

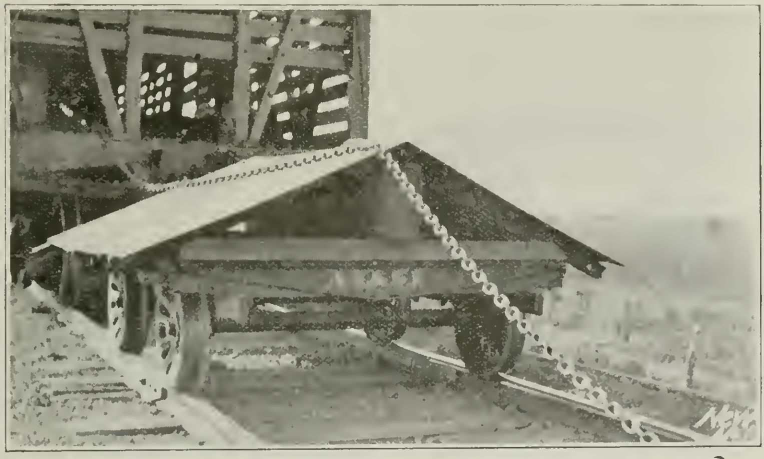
2. Madden Track Laying Machine—This machine consists of a light steel frame with a crab and fixed boom, which rests on one running rail and a small auxiliary rail which is carried with it, the gauge of the machinery being somewhat less than standard. The normal speed of the machine on 130-lb. rail is about one rail per minute, or a trifle faster. The organization with various sized gauge is shown below:

	Men
Pulling spikes	8
Throwing out old rail	4
Adzing and plugging	7
Changing tie plates	1
Madden Rail Layer—	
Tongman	1
Railmen	2
Windlass	4
Foremen	..
Applying splices and bolting	4
Gauging and spiking	9
Filling in spikes	11
Flogging	2
Total	53

On busy lines, where the track is obtained for stretches of 45 minutes to one hour, a trained gang of tongmen will work faster than the machine.

Rail Unloader—For unloading rail from stock cars. As the movement of stock cars west is an empty movement it is often desirable to use these otherwise empties to haul rail westward. Therefore, a special arrangement has to be made to unload rail from stock cars. There is a machine for this purpose. In connection with it a push car is necessary with a sloping protection of iron over it. This is formed by three bent rails and a covering of 3/8 scrap boiler plate.

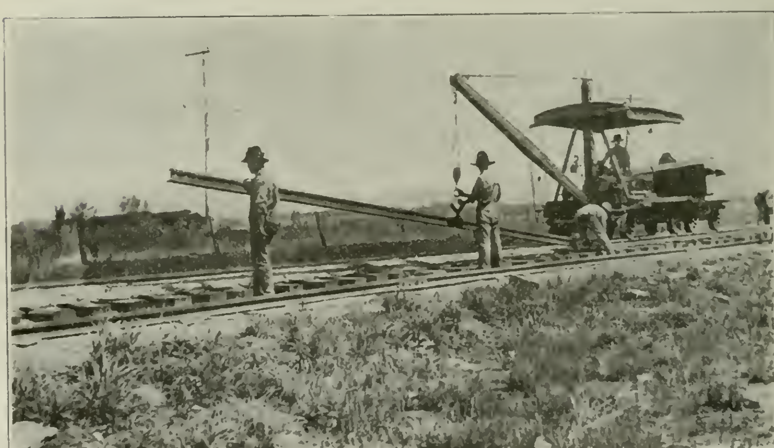
The covered push car which receives the rails is chained to the car loaded with rails by a chain 15 feet in length, depending on the length of rails to be unloaded.



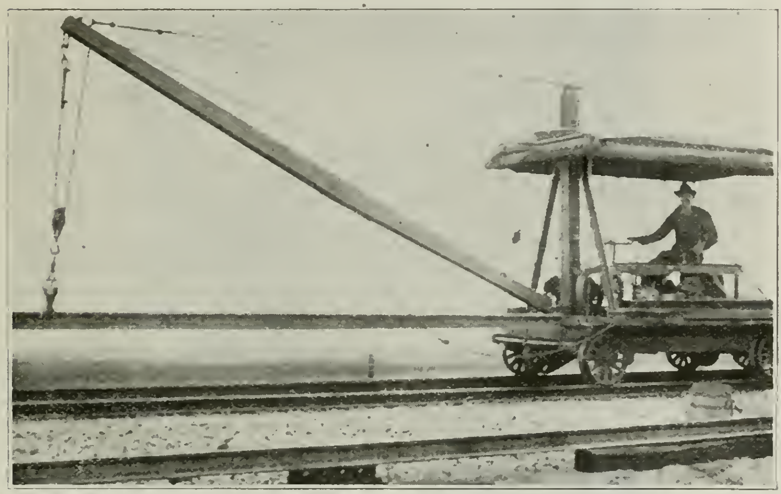
Push Car with Sloping Iron Protection for Unloading Rail from Stock Cars.

Unloading Rail from Stock Cars, Two Rails at a Time Falling Onto Push Car with Sloping Iron Protection.

Unloading Rail from Stock Cars, One Rail at a Time Falling Onto Push Car.



Rail Laying Machine.



Rail Laying Machine.

Ballast Cleaning Machines

The Committee has considered four mechanical devices for cleaning ballast, embodying ballast screens on which the ballast is thrown by hand, and a mechanical ballast cleaner which travels in an inter track space, and uses an endless chain of buckets which lifts the ballast and after cleaning returns it to the ditch; a rotary screen into which the ballast is thrown by hand; and the use of a ditcher and clam shell bucket by which it is hoisted onto a sloping screen, letting the dirt go into a car and the ballast back onto the track. The Committee wishes to encourage further use of these machines to gather more data.

Pratt Mechanical Ballast Cleaner—This machine travels in the center ditch resting on the ends of the ties, and is designed to clean the ballast in the center ditch only. An endless chain of buckets lifts the dirty ballast and throws it on a shaking screen. The clean stone rolls over the screen and returns to the center ditch while the dirt goes through the screen onto a pan, and is shoveled out by hand. The machine is driven by gasoline engine and will clear the traffic on both the adjoining tracks.

The designer of this ballast cleaner had in mind a small unit which would operate independent of passing trains, and would separate the stone from the dirt mechanically. Only three of these machines are in use and although some difficulties are presented in their operation, it is hoped that this beginning will lead to a successful ballast cleaner.

The organization used is as follows:

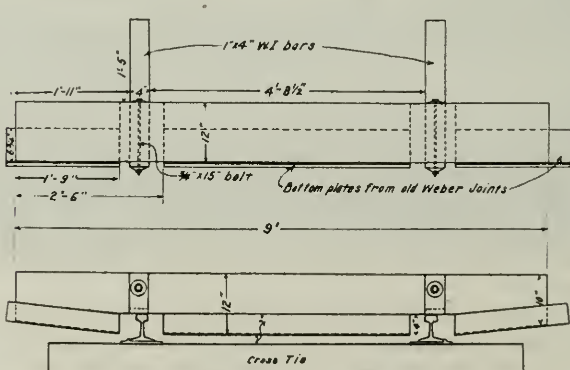
One man Directing the operation and working the machine ahead with lever intended for this purpose. This lever operates a small caterpillar traveler.
Two men Shoveling out dirt.
Two men Helping the ballast into the buckets and loosening ballast ahead of the machine if very hard.
One man Watching for trains, where traffic conditions require it.

Ditcher, with clam shell bucket and ballast screen mounted on gondola car—This operation consists of lifting the ballast from the center ditch with a clam shell bucket and dropping it on a sloping screen mounted on a gondola car. The dirt goes through the screen into the car and the stone passes over the screen and through a chute back to the inter-track space. The clam shell digs the ballast to a depth of about 10 inches below the bottom of tie and from end of tie to end of tie, but does not reach any of the ballast in the cribs.

This outfit will clean at the rate of one rail length in seven minutes. The cost of the train, including crew and laborers, is about $100 per day. The economy of the operation will depend on the ability to get the use of track.

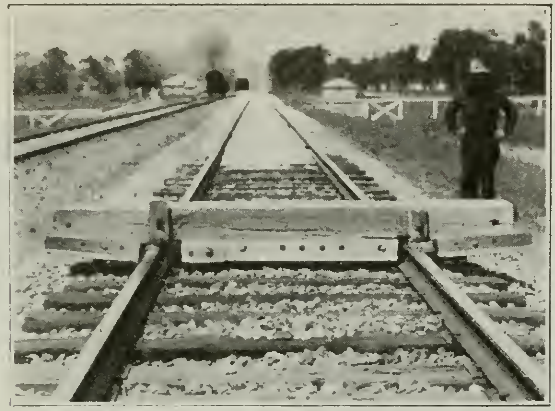
The organization is as follows:

Train crew, including:
Engineman,
Fireman,
Conductor,
2 Brakemen,
Ditcher operator,
Ditcher fireman,
3 Laborers—one laborer levels dirt in the car, another attends to the bucket and knocks down ballast at tie ends, and another levels the cleaned ballast in the center ditch.



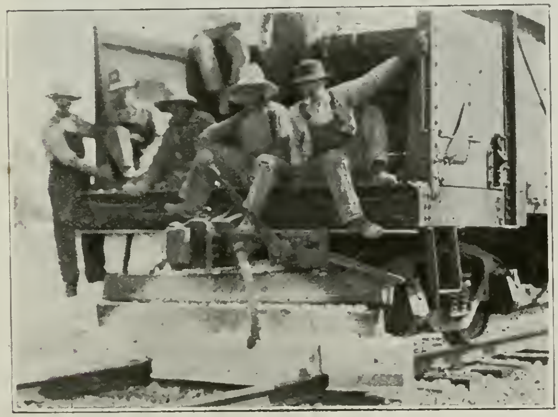
Tie used as ballast plow

Fig. 1.



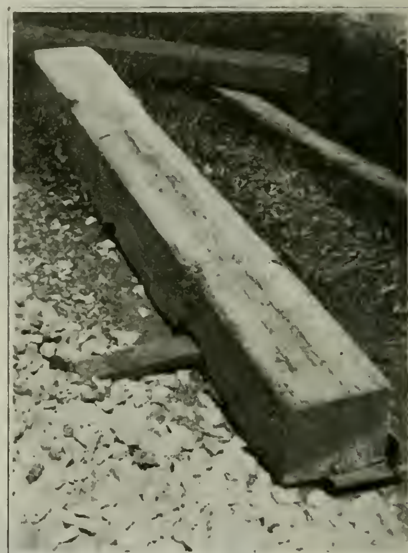
TIE USED TO PLOW BALLAST AND TRACK BEFORE BALLAST WAS DUMPED.

PLOWING.



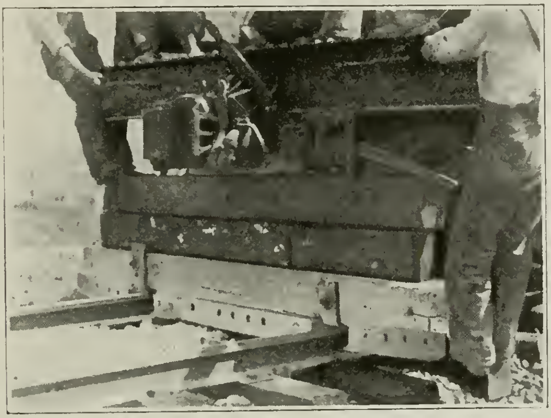
SHOWING PLOW AFTER THE ROCK FROM FOUR CARS WAS PLOWED.

Plowing.



Showing Top and Back of Special Tie.

Showing Track After Ballast Was Dumped.



Special Tie in Place with Cross-Ties and Wedge.

The Finished Job and Gang. Four Cars of Rock Ballast Were Dumped and Plowed Down in Twenty Minutes.

DISCUSSIONS

A

DISCUSSION ON YARDS AND TERMINALS

(For Report, see pp. 65-84.)

Mr. A. Montzheimer (Elgin, Joliet & Eastern) :—Mr. President and gentlemen, the report deals principally with two subjects, viz., handling of freight, and a report on classification yards. We have also made reference to the report of the sub-committee on passenger station, freight house and grain-weighing scales. Mr. C. H. Spencer, Chairman of the Sub-Committee on handling freight, is not present this morning, and I will ask Mr. F. E. Morrow, Assistant Chief Engineer of the Chicago & Western Indiana Road, to present the report of the sub-committee.

Mr. F. E. Morrow (Chicago & Western Indiana) :—Mr. Chairman, the report of this Sub-Committee for the year in the main is a progress report covering a discussion of warehouses in connection with l. c. l. freight houses. The sub-committee has not presented any definite conclusions or recommendations for adoption, but has simply presented certain data which became available to the sub-committee, with an analysis indicating as definitely as the data would permit certain relations which appear to exist between the various facilities of warehouses, viz: track capacity, team tailboard space, shipping floor space and elevators, as related to warehouse floor area, and in addition it calls attention to certain methods of handling l. c. l. freight by container systems, and city transfer of l. c. l. freight in various cities, which are being done by or tried out by new methods. The report is simply presented as a matter of information.

Chairman Montzheimer :—The Chairman of the Sub-Committee on passenger station, freight house and grain weighing scales is Mr. Hadley Baldwin, Assistant Chief Engineer of the Big Four. He sent a message that it would be impossible for him to be here today. The Committee have nothing at this time to report. It was hoped last fall that they could present in printed form their specifications on passenger depot and freight house scales, including motor truck scales, but they found this to be impossible, so at this time we have nothing on that subject to present.

The next is subject No. 5—Classification and Departure Yards. Mr. J. E. Armstrong, Assistant Engineer, Canadian Pacific Railway, is Chairman of this Sub-Committee, and I will ask him to present the report.

Mr. J. E. Armstrong (Canadian Pacific) :—The first part of the Sub-Committee's report is essentially an outline description of some of the newer hump yards that have been built; the Hawthorne Yard of the Pennsylvania Southwestern Region, the Cedar Hill and Providence Yards of the N. Y. N. H. & H., the Markham Yard of the Illinois Central, and the Niles Yard of the Michigan Central. It also mentions some yards which have been reduced from hump to flat yards or which are not just now being operated as hump yards, and gives some additions to the list of hump yards appearing on page 133 of Volume 15 of the Proceedings so as to bring that more nearly up to date. It outlines, in a general way, some of the things to be considered in connection with the construction and operation of sorting and departure yards and recommends the following definition for insertion in the Manual:

"Sorting Yard—A yard in which cars are classified in greater detail after having passed through a classification yard."

A part of the instructions to the Sub-Committee was to consider revisions of the hump grades now recommended by the Association. The Sub-Committee sees no need at the present time to revise these recommended grades.

Chairman Montzheimer:—The Committee on outline of work for next year is headed by Mr. H. J. Pfeifer, Chief Engineer of the Terminal Railroad Association of St. Louis, and I will ask him to present a short outline of the subjects that we recommend for next year.

(Mr. H. J. Pfeifer read subjects 1, 2, 3, 4 and 5—page 66.)

Chairman Montzheimer:—The Committee have the following conclusions to present (reading conclusion 1—page 66).

I would make a motion that that be adopted and placed in the Manual.

(Motion duly seconded and carried.)

(Chairman Montzheimer read conclusions 2 and 3—page 66.)

These two reports are presented merely as information, and as I understand it do not require a motion. That is all this Committee have to report, at this time.

The President:—This is very interesting and very valuable, and I should think that we would want to hear some discussion on it.

Mr. J. L. Campbell (El Paso & Southwestern):—Will the Chairman of the Committee give us an idea of what is in the mind of the Committee under subject No. 5, study and report on best ways of arranging terminals to reduce preparatory terminal leaving and arriving time of trains?

Chairman Montzheimer:—I do not know of any subject that is more important to the railroads of this country than the question of reduction in the preparatory leaving time and the terminal arriving time of trains at terminals. It is a well known fact that there is a great deal of time lost from the time the crew is ordered until they get out of the yard, and if the Committee can go into the subject and present something that will be of value to this Association, I think it will be well worth the time that we put in on the subject. There is a chance I think to make a report that will be of considerable value to the railroads of this country.

Mr. C. E. Johnston (Kansas City Southern):—I would like to ask if it is the idea of the Committee to bring that about in the design or redesign of yards or through schedule changes? You understand that the preparatory and other arbitrary time allowed varies for many reasons. It seems to me that if it is in the matter of yard design, it may be helpful.

Mr. W. R. Armstrong (Oregon Short Line) :—I would like to ask if this Committee has any data showing the percentage of time over an ordinary engine district consumed by these two processes?

Chairman Montzheimer:—Of course, we have not gone into the subject at all. We are merely recommending that the subject be placed as an assignment for the Committee to report on next year. I do not think that it will be the province of this Committee to take up that part of the question which deals with the negotiations with the brotherhoods, but it would be our thought to bring out for the benefit of the Association any pertinent facts we could, and I would think at this time it would be principally our recommendation to so arrange terminals and facilities that there would be less time lost from the time an engine is ordered out of the yard until it is coupled on the train. I think there is where we are going to be able to make some recommendations that may be of value.

Mr. E. H. Lee (Chicago & Western Indiana) :—This is really a very important question, and I am glad to see that the Committee intends to devote some attention to this particular angle of the terminal situation during the coming year. Of course, terminal time so-called, varies greatly between various railroads. On a line west of the Mississippi River, where divisions are long and where the division terminals are uncomplicated and simple, terminal time will be reduced to a minimum, perhaps. On the other hand, on Belt and Terminal Railroads of the eastern district, where conditions are very complicated, this terminal time runs into astonishing figures. The speaker quite a number of years ago had occasion to investigate this precise question.

Results were developed at that time astonishing both to the man who made the investigation and to the men who were operating the railroads. While a number of the operating men anticipated that this terminal time might amount to from 25 to 30 per cent, as a matter of fact it amounted to between 65 and 70 per cent of the total time of a transfer train. These percentages only applied to the particular conditions which existed at that particular time.

This indicates the fundamental importance of collecting the facts. As a matter of course the men responsible for operation in the American Railway Association will deal with facts as developed, and it is no part of ours to trench on their prerogatives; but such information is of extreme value, and I think our Association is particularly well qualified to develop many fundamental facts relating to this subject, the true value of which some engineers, as well as operating men, do not at this time seem to fully understand.

Mr. R. G. Kenly (Minneapolis & St. Louis) :—The speaker mentioned the lines west of the Mississippi River. Some of us have systems designed for small power. The function of road train crews is to take trains over the road and not to discover defective cars, etc., when trying to pull trains out of the yard. It is the function of this Committee to design the engine leads from the engine house to the departure yard, or vice versa, coming in; that it will take into consideration the question of facilities for pumping up train line, car inspection, if you please, and one thing which I think would be very pertinent—enlarge the functions of this Committee to take care of a bit of the road facility, after the train gets beyond the exact limits of the yard. It has always been my idea that even the poorest of our single track railroads ought to have a bit of second track extending beyond their most important yards, at least far enough out into the country for the train despatcher to get control of his train movement.

Mr. G. A. Mountain (Canadian Railway Commission):—I take it that the Committee will take into consideration in going over its work for the coming year, and before the matter is published in the Manual, the question of track centers. The 1915 Manual says that the body tracks shall be 13 or 14 ft. centers. My idea is 13 ft. is not enough and 14 ft. too much. I would like them to take that into consideration in connection with the yard centers.

Mr. E. R. Lewis (Michigan Central):—I would like to ask further consideration from the Committee of subject No. 6, transfer of lading of bad order cars. This was reported on last year, but the conclusions may possibly not give the investigator the most definite information. As I read the conclusions, they are divided into three parts: One, hand labor may be too expensive; two, there is justification for the use of a locomotive crane where six or more men must otherwise be employed; and, three, that the individual problem should be studied by the individual investigator. I would suggest further consideration of the subject next year, with a view to amplifying the conclusions.

The President:—Is there any further discussion? If not, the Committee is excused with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY LABOR

(For Report see pp. 669-705.)

Mr. C. E. Johnston (Kansas City Southern):—We have undertaken to boil down into the shape of certain conclusions, certain principles which we think will prove helpful with respect particularly to item one. We have considered this subject for the past two years, and find it beyond us to lay down rules or principles other than those of a general nature, and with the mass of data before us at all times we have decided to present for your adoption and publication in the Manual our conclusions shown at the bottom of page 672.

The President:—This important matter is now open for discussion, the conclusions on plans and methods for obtaining railway labor.

Mr. E. A. Frink (Seaboard Air Line):—I would like to inquire whether the Committee in conclusion No. 3: "Best results may be obtained by providing some officer or some organization to supervise the selection and care of employes," means that some one officer, or some one organization should be entrusted with the matter of selecting and supervising the employes of the entire system. If that is what it means, it is open to objection, because it does not seem to me a central organization could handle the question of obtaining track labor and mechanical repair men and bridge men so well as the organizations that are right on the ground.

Chairman Johnston:—That means that an executive general officer should be charged with the responsibility of looking after that important part of the business, centralizing it so that it may be run as an important part of the business. It simply means that this one man will be at the head of the organization to bring about these results, and we think from the data assembled on the subject something of that sort would be most helpful. We find there is no defined method of handling—one road may handle it through a fee labor agency, or through the boarding house boss; another road might handle it through their foremen, and another road in some other way, there being no definite organization to establish the rules under which labor may be employed, trained, cared for, etc. We think its importance justifies having a general officer to look after that department.

Mr. Maurice Coburn (Pennsylvania System):—We have had many discussions about methods of selecting employes, and as to whether intelligence tests, such as those the army use, should be adopted by us. I have seen statements made that these tests were applicable to railroads and similar organizations. Has the Committee discussed this to any extent? Do they think them worth while?

Chairman Johnston:—The Committee has discussed that feature a great deal, and its conclusion with respect to it is that each line must handle its individual condition, in some instances there are physical examinations before the men are employed or a short time after, but the

Committee is unable to lay down any rules for physical examinations or mental tests. We simply say that is an important item and we should work toward employing men who are physically and mentally fit.

Mr. W. D. Faucette (Seaboard Aire Line) :—I would like the chairman to explain how he understands the machinery of conclusion No. 3 would work. Suppose the officer who is to supervise the selection of men is 1,000 miles away from where the men are to be selected, such as track-laying gangs, bridge gangs, crane gangs, clerical help, etc.?

Chairman Johnston:—This man would be the head of a personnel department. He would not personally supervise the employment of men 1,000 miles away, but he would get a record of their physical examination and other data. He would keep in touch with the particular section of the line on which a certain number of men are required during certain seasons of the year, and he could be in touch with the officer who might wish to shift the men from place to place. It would be something on the order of a personnel department, and it is left to each road to determine the extent to which they could use it. We feel that this item of railway maintenance labor is so important that some officer should make it his business to look after it from the general standpoint, and not let it go along as we are doing, with each and every subdivision of the road handling its own problems, because in this way there is much lost motion and additional expense.

Mr. S. E. Shoup (Kansas City Southern) :—It seems to me the idea expressed in paragraph 3 of the conclusions is that there should be some general officer in charge of this work as a whole. We do not expect the superintendent to superintend an entire system, he works under a general superintendent, and under the superintendent are trainmasters and others to handle the detail. It would depend on the extent of the road, as to the size of the organization that would be required, but it seems to me that every road should have permanent forces at strategic points on the line working under the officer charged with this duty, who would control the policies and be in touch with the broader aspect of the labor requirements and available supply and handle such matters as they should be handled.

Chairman Johnston:—The intent of the Committee is exactly what the report indicates—that the best results may be obtained by providing some officer or some organization to supervise the selection and care of employes. That means it is left to each individual line to work out in its own way.

Mr. E. A. Frink:—This subject is of sufficient importance to be gone into a little further than the Committee has gone in recommendation No. 3. When this Association is given the design of anything for consideration they are not satisfied with laying down broad principles, as a rule, but go into details. If this Committee could give us a plan of the organization it has in mind it would be more helpful. I am aware that the employment of railroad labor is handled in a loose way, left to the individual head of department, individual foremen, or individual man sometimes to employ labor, and that does not tend to produce the best results. I agree that the matter should be supervised by a central authority, but if the Committee would map out how that can be best accomplished it would be much more helpful.

Chairman Johnston:—We feel this way about the matter—this is the result of some few years' study of this problem, and to cover it generally is about as far as the Committee feels it should go. If there is any better plan to be suggested to guide us with respect to this particular item we will be glad indeed to have it. What we present here is the result of much study and the assembling of data from many sources and from all over the country. If anyone here has something better to suggest we would very much like to have it.

Mr. Frink:—I did not mean to criticize the work of the Committee but my suggestion was along the line of making the recommendation fuller as to detail.

Mr. R. G. Aylsworth (Chicago, Burlington & Quincy):—I believe it would be very helpful if the Committee would present a brief resume of plans now being used, if there are any such. I think the greatest value of the work of the Association comes from empirical study. I am sure I can better judge what system should be employed by studying the report of plans as wholes rather than selected features.

Chairman Johnston:—The last year's report of this Committee contains a list of some 80 lines and sets up generally their practices.

Mr. C. E. Lindsay (New York Central):—The subject is one of great importance, not only for the present maintenance of way organizations, but for such organizations in the future. The past four years has brought emphasis on the question of seniority—once in the service, unless you can show a man is derelict in his duties or incompetent, he expects to remain in the service. Therefore, it behooves us to lay the foundation now for a system on which we will allow only those to enter the service who give promise of development and adaptability to the service that is necessary.

Mr. A. L. Davis (Illinois Central):—I ask Chairman Johnston if he hopes to receive, later on, reports from those bodies that he recommends to study this question.

Chairman Johnston:—You understand the Committee recommends the adoption of conclusion No. 3, which has been read several times, and leaves it to the individual lines to train the organization and operate it as it sees fit. This Committee has no idea of getting any reports from any organization, as it does not outline how the organization shall be built up.

Mr. Davis:—If a central body is organized on each road to correlate the systems of the different departments in employing labor on the road, then it seems to me it would be well to follow the question a little further by having these central bodies get together and analyze their separate systems and compare the results; your Committee would be the proper body to follow this up.

Mr. Lindsay:—Will the Committee accept the substitution of the word "problem" for the word "question" in the first conclusion?

I assume in conclusion No. 4, the living conditions, so far as they are provided, are to be provided by the railroad contractor, and I believe that should be set out more definitely.

Chairman Johnston:—The Committee will agree to that.

Mr. F. J. Stimson (Pennsylvania System):—It is not clear to me why the Committee has so modified their conclusions as to practically take all force away from them by using the words "may be." I would suppose the Committee would want to say that "the best results *will be* obtained," and it seems to me such language should be used in this conclusion.

Chairman Johnston:—I doubt if the Committee is in a position to say that the best results will be obtained. We leave it to the individual lines to work out a system that will suit their condition. We do not outline any definite plan. We put it in the shape of "may be," as a suggestion. We would not be in position to say that the best results will be obtained by any particular organization, without investigation of the conditions on each road.

Mr. Stimson:—I note that from the consideration the Committee has given this subject that it has determined upon a general broad principle, which is, as has been stated by the chairman of the Committee, that there should be a general head to the employment department. In other words, while an individual railroad might have its own way of laying out the organization and applying the general principle, the Committee had decided that as a general principle the employment and handling of labor should have a head on each railroad. Having decided that principle to be correct, why not say so without the equivocation of "may be."

Chairman Johnston:—That is the purport of what we have presented.

Mr. Stimson:—There are several methods before you and you are supposed in this report, as I understand, to select a method. Why do you select it? Because it will give the best results. I can understand the Committee not recommending a permanent organization, but it does seem to me it should go on record as to what system will, in its judgment, give the best results.

The President:—Is there any further discussion?

Chairman Johnston:—I move that the six conclusions beginning at the bottom of page 672, be adopted and published in the Manual.

(The motion was duly seconded, put to vote, and carried.)

The President:—The conclusions will be published in the Manual.

Chairman Johnston:—The next is report upon methods for training and educating employes in engineering and maintenance work.

(Reading matter under Appendix B, page 674, down to the words "first essential to success.")

We have given this subject about two years' careful study, and as I stated, we think it is beyond us to deal with it except in a general way, and we are submitting for the adoption and publication in the Manual the following conclusions:

(Reading conclusions 1 to 6, pp. 678-9.)

The President:—Are there any remarks? There certainly should be some discussion on this. Some college men should speak on No. 6.

Mr. J. A. Stocker (Toledo & Ohio Central):—I was interested in the President's remarks in regard to the treatment of the young engineer. I think most of us who are no longer the young engineers have come up through the school of hard knocks, starting at $40 or $50 a month, and have now reached positions of more or less importance. It occurs to me that many of us who are the heads of the engineering departments forget how we felt as we came on up the line, and fail to give our subordinates the treatment that we needed to keep us cheered up, encouraged and enthusiastic for the railroad service, and do not do our full duty towards these men along the lines of training the men, and also in the way of encouragement.

I have seen many a fine prospective engineer leave the railroad service under conditions which in my judgment reflected seriously upon the railroad management. Most of us are standing between our organizations and a superior, the president, the vice-president, or general manager, who may not appreciate the conditions, may not realize the value to the railway company of training competent engineers, and I wonder whether we always do what we should do to present the case of the engineering organizations to the superiors who control our actions, and incidentally control our treatment of all of these men.

I long ago resolved that I should never stand between one of my subordinates and promotion, and should never fail to go to my boss and present the case of any man who reported to me whose future in the railroad service I believed depended upon my support.

I feel very strongly for the young engineers who are coming into the railroad service. I have a 16-year-old son who thinks he is going to be an engineer and I wonder whether I shall encourage him or shall not encourage him. It is unfortunate that after twenty years in railroad service I should not be enthusiastic for my son to enter the service, and the reason I am not enthusiastic, gentlemen, is because I have seen many a boy come into the service, progress to a certain point, and be entirely sidetracked, when I believed that the man in charge of that boy could have steered him into some course that would have encouraged him and made a railroad man out of him. I resolved, as far as I am concerned, that I should represent my men before the boss, and I believe we all should do so.

I believe we can do a wonderful work for the railroad organizations by training these young fellows and by seeing to it that they are not discouraged and driven out of the service. (Applause.)

Mr. C. R. Harte (Connecticut Company):—I have listened carefully to your opening address, Mr. President, and was impressed with it. When a young man puts his foot on the bottom of the ladder in entering the railroad service, he should or must look to the top. If the railroad will have a well-defined ladder for an engineer entering the service, it will save them much trouble and will give great benefit to the engineer. The young man entering the train service has a short ladder with wide steps in it. There are many men today firing engines who are qualified engineers; there are many men braking on trains who are qualified conductors, so that the opportunity for their advancement is very much more restricted than that of the young engineer, and if the railroads will have a well-defined policy for the engineers, and let them see where the top of the ladder is and what the rungs are, it will be a great help to them.

Mr. Maurice Coburn:—It seems to me that one of the fundamental mistakes that is being made constantly on railroads is where the man at the head of the department, wherever he may be, tries to keep all the fun to himself; where he wants to do all the planning; where he keeps his policies to himself. If a subordinate is to be made loyal, he must be encouraged, he must understand, as far as possible, the aims and policies of the management, so that he can try to work in line with those aims and policies. It ought to be more the measure of a man's success as to the number of high-class men he can train under him. If the idea permeated the railroads everywhere that they should be run like a high-grade school, I believe we would all be happier.

Mr. W. H. Courtenay (Louisville & Nashville):—There is a way in which the man at the head of the engineering department can help a young man. If a young man is charged with any investigation and makes a report, and the report is exceptionally good, and does not need any modification, it has been my practice when reporting to my superior to submit the young man's report, for it gives the management some idea of the ability of the men in the engineering department; and I think in fairness to the young man that is a good plan. It brings him to the attention of the higher officers, and it has in the past resulted very much to the benefit of a good many whom I know.

Prof. A. N. Talbot (University of Illinois):—As the President suggested that college men might speak of this phase of the question, I have been hoping some of them would talk. I do not want to let the opportunity pass if the other professors will not speak. I am pleased with this report and with the remarks made by the President this morning. College men, college professors generally, have been wondering for years why it was that the technical graduates were going into other lines of work rather than into railroad work. When I graduated many years ago the railroad field was almost the only field for the technical graduate. Now, as stated by the President, only a small proportion of the civil engineering graduates go into railroad work, and he has, I think, touched upon one of the reasons for it, the small pay as compared with the pay which may be secured and the opportunities for advancement in the other lines of engineering, as well as the relatively higher compensation to the non-professional railroad man.

I hope that this suggestion will be taken up by railroad men generally and an effort made to do, as has been suggested here, give the young man a better opportunity.

I am particularly pleased with the Committee's recommendation concerning the training and education of the younger men, and the necessity for giving them the opportunity to take part in conferences and to take more responsibility generally. I think we all agree, we know it, that when a man graduates he is just beginning his education. I am sure that all through my life I have been having education and training. In railroad work particularly a man's education and training have just begun when he enters the railroad service. I am very much pleased with the report of the Committee. (Applause.)

Mr. W. L. R. Haines (Pennsylvania System) :—I think that Mr. Courtenay's suggestion that the reports of the young engineer should be forwarded needs a little supplementing. When he makes a report containing recommendations, which for some reason cannot be followed, he should be advised in what respect his report is faulty. Frequently the young engineer does not know why his recommendations are not followed and is apt to think his report has been "pigeon-holed." The pointing out of his faults is quite as essential a part of his education as any other part of his training.

Mr. H. T. Porter (Bessemer & Lake Erie) :—Mr. President, I have no doubt that the practice I am about to speak of is followed quite generally, and I only mention it because it has not been spoken of here this morning. When a young man enters our employ, I generally have a little conversation with him and I say to him: "Now if at any time you find that you are not getting along as fast as you would like to, and you hear of an opportunity of doing better elsewhere, you can follow this matter up openly, because I promise you that I am ready to help you. Also if you can get a better position with some other company, it wiil not injure you here, and if at any time you can do better, however inconvenient it may be to me to lose you at that time, I will not stand in your way, but will give you all the help I can."

Mr. E. F. Kultchar (Chicago, Burlington & Quincy) :—Mr. Chairman, as one of the younger members, I would like to go a little further on what Mr. Haines and Mr. Porter have just said. The young engineer finds himself very often limited to the work he is put on. He sees perhaps while he is on a construction job that some man from another department, often from the train service, is promoted to an operating position, which he recognizes as a superior position, perhaps more on account of the pay, but also on account of the broader responsibility. The young engineers would like, I believe, to be given opportunities where they have a chance to broaden in the field that they cannot learn in college; that is, the handling of men and organization of men under them.

Mr A. M. Knowles (Erie) :—I wish to call your attention to one fact which has not been mentioned here today and is very frequently overlooked in considering the proper and fair compensation of technical engineering employees as compared with other classes of non-technical railroad employees.

That of which I am about to speak may be one crucial reason why such a small percentage of technical engineering graduates accept employment with railroads, as President Downs mentioned in his address this morning.

We all know that the technical man who has gone through college has had to put up a certain amount of cash, usually $3,000 to $4,000, but sometimes much more. We also know that during the three or four years in preparatory school and four years or more in college the technical man has had little or no time in which to earn much if any money, but during which time had he elected to be engaged in any one of the railroad positions, namely, fireman, flagman, switchman or car repairer, which President Downs mentioned this morning, he would have earned not less than $12,000, and would have been perfecting himself in his position, and most likely would have been promoted with higher compensation than he started with.

The difference between the $12,000, after deducting living expenses, and $4,000, represents the capital invested in his education and training to fit him to undertake technical engineering work.

It would seem, therefore, no more than reasonable and just that an employer requiring the services of one having technical engineering qualifications such as the technical graduate has should be willing to pay enough more for that special ability and training than he would pay his other non-technical, inexperienced employees. But such, according to President Downs' own statement, is not the fact. Instead, the technical graduate is penalized for having applied himself to his books to acquire his technical knowledge and training, and putting up good money for it and thereby making it several years later for him than for his non-technical fellow workman when he can begin earning a living and he not only does not receive in return the equivalent of the capital invested, but not even fair interest on it besides a living wage.

Other employers of engineers realize this and bid higher for the technical graduate's services than the railroads do and higher than non-graduate, non-technical men without experience receive. Is it any wonder then that a sensible graduate steers clear of employment with the railroads?

Mr. R. H. Ford (Rock Island Lines) :—One of the greatest difficulties that the young engineer has to face on entering railway work is the complex organization of a railroad. Departmentalism is one of the serious features, and it usually works to their detriment. Up to this period of his career the young engineer is necessarily more of a technical than a practical man, and too frequently his superior officer, realizing this, holds him so long on design, specialties, or on staff duties, as to afford little or no opportunity for broad development, thereby narrowing his field and proportionally decreasing his opportunities for future advancement. All men, whether or not they are engineers, have certain natural tendencies that are susceptible of easy development if opportunity offers. To be qualified to fill superior positions, the technical and the practical will ultimately coördinate with the administrative and executive functions, and it certainly follows that unless the young engineer can have a fair opportunity to develop these to the extent that he has them in him, he will not get very far in railroading; or, if he is kept too long in the Engineering Department, as he usually is, the same thing will result. Departmentalism, more than any other cause, has served to keep the trained engineer from being a more potent force in railroading. An engineer may become very expert in some technical line of work in some department, and yet be completely lost because nature will in due time intervene and his habits and ways have so crystallized that it is too late for him to broaden out and develop as he might have otherwise done.

Accounting, Mechanical, Transportation and General Operation are too frequently practically closed to the man entering the Engineering Department, unless the superior officers take a special interest in him and make an effort to see that it is not so. Too frequently executive officers forget that they have a reservoir from which rescruits can be drawn who, if given the opportunity for development, would bring to railroad problems a mind trained for logical thinking. While I have little patience with the engineer who feels that his college diploma should advance him over the practical man from the transportation or other departments, I do feel that he should be given a fair break and a little assistance in his efforts to qualify himself for the future. The Assistant Engineer and the Division Engineer are usually men with considerable length of service, and they should certainly be given an opportunity for development and a square even break with the so-called practical man of other departments for advancement to superior positions. This, of course, is done on some roads, but, unfortunately for the business of railroading, it is the exception and not the rule.

There are in this Association engineers who were afforded the opportunity to develop and show their ability—and they took it. They have gone up the line and it is intensely interesting and instructive to study the training and opportunity which came to them. However, while there are exceptions, of course, it is a strange thing that as a rule the average young engineer seems to get less consideration from such men than he gets from the so-called practical operating men—which ought not to be the case.

If the very unusual address of President Downs will be practically applied, and so sink into the minds of the members of this Association that before leaving the convention they will resolve that during the next year they will find a way to give these young subordinates an opportunity for development in keeping with individual ability and the desire to go ahead towards the goal of *practical railroad men,* it will mark an epoch in the annals of this Association and will be of greater value to the roads in general than all the other work done at this session.

Mr. P. H. Winchester (New York Central) :—I think these remarks lead up to the problem that it is up to the railroads themselves to make the railroad work more attractive for the young engineer.

It is a fact that within the last few years the engineering graduates of the various schools of this country have been attracted less and less to the railroads, due largely to the attitude of the railroads themselves. The railroads in the long run are going to lose by not drawing men from the engineering schools as they have in the past. There should be some method worked out that will make the work more attractive.

Mr. W. M. Camp (Railway Review) :—I think it is evident, from the character of this discussion, that the Committee has made some good points. I was particularly impressed by the remarks of the first speaker, from the Toledo & Ohio Central, and by the remarks of Mr. Courtenay; but, for that matter, all of the discussion has been to the point. These six conclusions are most excellent, and every one of them might be emphasized. I think they might well be put in a frame to hang where the chief engineer might look at them occasionally, and also to encourage the young men who are working under him.

A young man applying for a position is a good deal like a toad—one cannot tell which way he is going to jump. It is a difficult thing to form a correct judgment of a stranger, to know what his disposition will be or what his ability will be. Both of those things go together to determine the usefulness of a person.

In this conclusion No. 2 it admonishes engineers not to permit a young man to work in the office too long before finding out what ability he can display. Find out what type of man he is, and if he is not of the type that will develop into an engineer, he is not a fit man for the position.

Now, there is another phase of this question that has not been mentioned here this morning, but it is important to think about. The training of the majority of engineers sitting in this room has been through the construction department, and perhaps the majority of you came out of college. Some of you carried a chain for a while, and then took a rod, and later were put on a level; and then you were advanced to a transit; and as you developed in responsibility you were put in charge of a section of new construction, and figured up the estimates of the contractor, and finally you got to be Division Engineer. That schooling of the engineer is going out of existence, because of the rapid falling off of railroad construction in this country in the past fifteen or twenty years. In the future there is not going to be the same opportunity to put young men into the game where they will have to assume the responsibility of handling a party of men and be responsible for a certain piece of work; but more largely hereafter they will start in at the drafting board. As Professor Talbot said, the man who starts out in railroad work has to start at small beginnings and develop through them.

College education is intended to train a man to think, but in engineering practice he must have something to think about before he can develop his intellect very much in that direction. It ought always to be in the mind of the Chief Engineer or the Division Engineer who has these young men working in the office, doing partly clerical work, that these are the men who are going to take the place of the present engineers who are in a managing capacity. Occasionally the young engineer can be sent to lay out something or to report on a piece of work. In other words, try to give him an idea of what is being done on the outside, as well as on the inside, where only the planning is being done.

An engineer once told me it took two classes of men to run the engineering department of a railroad—men to plan and men to construct. I think the Committee has struck a good point when they recommend here that men be shifted around a little, and the suggestion of rotation in service is an excellent one. Send the young man out and put some responsibility upon him. After all, responsibility is what develops men, whether it is in engineering or in other lines of work. A man will never amount to much in this world unless he assumes some responsibility, and stands for something. These recommendations seem to encourage that idea, and so they are good.

Along that same line it strikes me that engineers have manifested an inclination to gain full knowledge of the operation of different departments of the railroad and rotation in service will bring that about. I think this is due perhaps to quite an extent to lack of encouragement and I believe the younger engineers should be encouraged along that line.

Nos. 3 and 4 also impress me that there ought to be a desire among engineers to familiarize themselves with operation and methods of handling business in other departments.

The President:—The motion before the meeting is that the conclusions found on the bottom of page 678 and top of 679 be adopted and published in the Manual.

(Motion put to vote and carried.)

(Chairman Johnston read conclusions from discussion of subject (b) 1, 2, 3 and 4, page 679.)

Chairman Johnston:—The Committee recommend that these conclusions be adopted and published in the Manual, and I so move you.

(Motion duly seconded and carried.)

The next section of the report, report on standard method for performing maintenance of way work for the purpose of establishing units of measure of work performed, will be presented by Mr. Earl Stimson, Chairman of the Sub-Committee.

Mr. Earl Stimson (Baltimore & Ohio):—Mr. Chairman, this subject has been under consideration of the Committee for several years, and there is really nothing new in it. The report is an attempt to reduce to a systematic form certain rule of thumb methods which we have all used in a more or less crude way for a number of years. It goes into considerable detail and may appear to the person casually looking over the report as rather elaborate, but there is nothing in it that some of us have not already done and probably have been doing for a number of years. The Maintenance of Way Department is not furnished with any accurate cost data by the prescribed methods of accounting. Expenditures are reported in lump sums under arbitrary accounts and sub-accounts, and they are generally furnished from thirty days to six weeks after the work is finished, so they are of very little use to us in correcting any faults in management, or any excesses in expenditures that should be gotten at immediately. Other departments have more elaborate systems of accounting, a large part of which is supplemental to the regular accounting, but in the Maintenance of Way Department apparently this has never been thought necessary, and the supplementing of the prescribed accounting has been rather meager. This report presents a method of detail accounting which is rather simple in application and furnishes through a form of daily report an accurate record of what has been done by the individual gangs each day, in other words, a form of report that may be looked upon as the "train sheet" of the Maintenance of Way Department, by means of which you may know within a day or two at most what you are doing as compared with the standards of performance you have established. If the Association will permit, I will read a paragraph or two from the preamble to the report, which expresses a good deal better than I can do what the Committee has to offer. There is a statement outlining the rather unfavorable conditions under which maintenance of way work is carried out, particularly with reference to fluctuating forces and uncertain program. The report then proceeds:

(Reading paragraph commencing on page 680 and ending top 681.)

The features of the plan are submitted under four headings as follows:

(Reading headings 1 and 2 on page 681 and 3 and 4 on page 682.)

There follows an outline of each one of these features, supplemented by samples of the manner of applying the established principles, which are given in the exhibits. It is felt by the Committee that these exhibits are an essential part of the report, although they are not expected to be taken as standards to be followed in detail. Each road in working out this system and applying it may see fit to vary the methods to fit their local conditions, which would effect modifications in the time schedules, etc.

The conclusions the Committee have to offer are as follows:

(Reading conclusions on page 686, with the recommendations following.)

The recommendations of the Committee are as stated and to bring the matter before the Association I move their adoption.

The President:—Mr. Stimson has given a great deal of thought to the question of units of measure of maintenance of way work. It may interest you to know that he is a reporter at the International Railway Congress in Rome, to be held in April—next month—and he has a similar report to give to the world on that subject.

You have heard the motion. Are there any remarks?

Mr. Camp:—Mr. Stimson has given more attention to this subject than any other member of our organization, and he has made something of a record with it. For several years before the war he had this system in practice and it was going well, but it was discontinued during the war. There are several interesting features of it, one of the most important being that the engineer of maintenance keeps records which show just what he is doing. It presents to my mind the only fair method of comparing work that may be under way at different points. The engineer of maintenance who will lay down a system of this kind and follow it up will be so familiar with the results he is getting that outsiders cannot come in and criticize his work as they do some other departments of railroad work. Railroad men, particularly in the maintenance of equipment, have been open to attack by outside men who knew very little of what they were talking about. Fifteen or 18 years ago there was a very distinguished man who came out and made the assertion that the railroads were wasting a million dollars a day. You know his sweeping statement struck the country like fire before a wind, and people actually believed in it. I am speaking now of popular mind, people who knew nothing accurately about the subject. The man who made that assertion did not know what he was talking about, because when he was challenged to specify in what way the railroads were wasting a million dollars a day, he said: "In shop work, in their repair of equipment." One railroad general manager took pains to look into it, and found out that the total cost of maintenance of equipment in the United States was only about $240,000,000 a year, and as that did not average up to a million dollars a day, so the "expert" who made that assertion fell down. Nevertheless, he made a false impression on the public and it stuck. Now, if maintenance engineers would adopt some system of this kind they will find not only that they will save money for their roads, but make themselves immune from the attacks of outside "specialists" and "quacks" who deal in generalities. Besides, it is very important to get at this unit cost proposition and for the engineers to know what the work is costing them, so as to be in position, where work is costing too much, to apply the remedy and economize.

(The motion was then put to vote and carried.)

The President:—The Committee must know by the expressions from the members from the floor that their work is appreciated. It is a difficult subject to make a comprehensive report on.

The Committee is excused with the thanks of the Association.

DISCUSSION ON BALLAST

(For Report, see pp. 130-158)

Mr. F. J. Stimson (Pennsylvania System):—In the absence of the Chairman of the Sub-Committee on revision of Manual, I will present that subject myself. There was only one matter taken up and that is the inclusion of a definition for "spot board." The occasion for this comes from the action of the Committee on Ballast, in including under tools for use in ballast work a spot board. The Committee believes that this additional definition should be included in the Manual. I move that the definition of "spot board" be approved and included in the Manual.

(Motion seconded and carried.)

Mr. C. W. Baldridge (Santa Fe):—The Sub-Committee on item 2, "application of ballast," were given charge of the matter of reporting on the cost of ballasting and the application of ballast, and you will find the matter referred to on page 133. Under the heading of the "application of ballast" we prepared a chart for a small ballast gang, supplemental to the chart which was submitted one or two years ago for a larger gang.

On page 133 we give a statement regarding the small ballast gangs and the cost of ballasting.

The remainder of the report is a compilation of the reports that we were able to get from a number of railroads in reply to questionnaires sent out as to the cost of ballast work in detail. Some two years ago a blank was sent to many railroads in the country with a request for information in detail. Some 4 or 5 roads returned reports on the blanks or in the form in which the blanks were made out and we have condensed these, as shown at the bottom of page 135 and following pages.

A number of other railways sent us information as to the cost of ballast, but not in the form in which we had requested it, still the Committee considered that it was best to give as much of the information as we could and you will find this information given in Appendix B, in the best form in which we were able to prepare it, and as these figures are the actual cost of ballast as reported by the various railroads they will undoubtedly be of some benefit to us.

The detail cost of ballasting was particularly desired, seemingly, by the valuation people originally, and after they had brought the question up a good many others found it would be of considerable value. These costs of ballasting as printed here are offered as information to be printed in the Proceedings and are not offered for inclusion in the Manual, inasmuch as they are information only. The only portion of this report intended to be included in the Manual is the chart for small ballast gangs with the clause accompanying the chart given on page 133, and I offer the motion that the chart on page 134 and the clause on page 133 be accepted for inclusion in the Manual.

(The motion was put to vote and carried.)

Chairman Stimson:—I will ask Mr. Holt to make the report on ballast tools.

Mr. A. G. Holt (Chicago, Milwaukee & St. Paul):—Last year the Sub-Committee on ballast tools planned for nearly all ballast tools used except a shovel. A tentative plan of shovel was submitted, which is shown on page 154. This Sub-Committee felt they should go further in respect to the shovel and submit herewith additional plans. These are shown on pages 154-157. The idea of using the straight handle as shown on page 157 is that of economy in the use of timber, ash becoming comparatively scarce, as it is possible to get 4 straight handles from the same size block as will produce 2 of the other handles; it was also thought that more attention should be given to the handles, and not as much to the blade as has been considered necessary heretofore.

It was therefore decided to draw up a set of specifications in which the properties of the handle was stressed greater than in any specifications we have been able to get hold of before.

I wish to call your attention also to the physical properties set forth in the specifications and especially to the tests which are suggested for the blades. We have gotten away from the chemical analysis entirely in the steel and confine ourselves to a Brinnell hardness test, which is an easier test to make than the chemical analysis.

In the Committee the feature of joining the blade to the handle was thoroughly discussed and you will see that these three plans show respectively a riveted blade and a welded blade adjoining—any one of these three plans can be made to fit in with the specifications.

Chairman Stimson:—While the recommendation of the Committee is to the effect that the specifications for ballast shovels shown in Appendix C be approved as recommended practice and printed in the Manual, it has seemed to those of the Committee with whom I have talked this matter over since the report was printed, that it would be better to present these specifications in the nature of information instead of recommended practice, inasmuch as they have not had the test of time and the results of experience with them, that it seems wise that they should have before they are adopted as recommended practice.

I therefore move that the specification for ballast shovels in Appendix C be accepted as information.

The President:—Did the Committee confer with the Track Committee on the subject of shovels? They also have some recommended designs of shovels.

Chairman Stimson:—We did not have any conference with them.

The President:—I will say that there are also recommendations in the Track Committee report regarding shovels, which may be found on page 598 of the report to be presented at this meeting. I mention that now so we will not get into a jam.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—Is it the thought of the Committee that there should be a shovel for handling ballast and also the shovel ordinarily used along the right-of-way?

Chairman Stimson:—I think I can say there is not that thought. The Committee on Ballast in their report to the convention in 1921 included shovels, and the Committee's action this year was merely along the line of having that study extended, in order to present something further along that line, and it did not occur to the Committee until it was really too late to have a conference with the Track Committee, that such a conference was expected.

Mr. E. A. Frink (Seaboard Air Line):—My recollection is that the instructions were to design ballast tools, in consultation with the Committee on Track, and inasmuch as two designs of shovels have been brought out, it is evident that the matter is not in its final form.

It seems to me that both the specification and the design for shovels is exactly in the proper shape for presentation to the American Engineering Standards Committee. The proceeding of that Committee will be to get the opinion of every party at interest, get a sectional committee composed of representatives of every party at interest, manufacturers and users in general, and to have these parties at interest agree on a type or types and a specification or specifications that will fill the need. Then it will be adopted as a tentative standard, after that it comes back to this Association, through its Committee on Track, or Ballast, or Standardization, whichever appears the most desirable, for presentation at our convention, and approval or objection.

I move to amend the motion before the house by substituting this motion: That the design and specifications for shovels prepared by this Committee on Ballast be presented to the American Engineering Standards Committee for their procedure.

Mr. W. P. Wiltsee (Norfolk & Western):—The Track Committee, in considering the subject of track tools, felt that the shovel was more a general track tool than a special ballast tool. Therefore, they prepared plans also, and it was not discovered the two committees were working on the same thing until the report was sent to the Secretary. Such small differences as exist between the two can be reconciled.

Mr. J. L. Campbell (El Paso & Southwestern):—In the outline of work this Committee was instructed to collaborate on this question with the other committee. Apparently they overlooked the instruction.

Chairman Stimson:—The fourth subject is "Review of Previous Reports." That will be presented by Mr. Harris.

Mr. G. H. Harris (Michigan Central):—At the time of the recommendations for future work were made by the Committee on Ballast, it was overlooked that there existed in book form a General Index covering all the subjects pertaining to ballast which ran up to 1919, and as each year's Proceedings has an index covering the subject matter in it, it was felt that the preparation of any report covering the matter that had gone before would be merely a duplication of the index and would not be any more available in any year's Proceedings than in the former Proceedings, and it was felt as in a short time the General Index would be brought up to date that any report made at this time would not be of any practical benefit and the Committee recommends that the subject be dropped.

The President:—If there is no objection, the recommendation of the sub-committee that the "Review of Previous Reports" be dropped will be agreed to, and if there is no further discussion the Committee will be excused, with the thanks of the Association.

DISCUSSION ON IRON AND STEEL STRUCTURES

(For Report, see pp. 159-163)

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—On subject No. 1, the Committee offers a few changes in the Specifications for Steel Railway Bridges, which were adopted in 1920.

(Reads change in Article 47.)

In behalf of the Committee I move that the change in Article 47 be approved.

(Motion seconded and carried.)

(Reads change in Article 48.)

In behalf of the Committee I move that the change in Article 48 be approved.

(Motion seconded and carried.)

Chairman Selby:—There is a change in Article 157 which is not in the Bulletin, but was adopted after the report was sent in. It is proposed to add to Article 157, under the table of physical properties, the following:

Elongation in 2 in. minimum per cent 22. The remainder of the article provides for the other properties.

In behalf of the Committee I move the adoption of the change in Article 157.

(Motion seconded and carried.)

Chairman Selby:—There is a change in Article 243. All after the word "engineer" in the fourth sentence is to be omitted.

I move the adoption of that amendment.

(Motion seconded and carried.)

On subject No. 2 we present the Specifications for the Erection of Steel Railway Bridges, given in Appendix A.

(Mr. Selby then read portions of these specifications.)

The President:—The report is received as information.

Mr. Lindsay:—I have one or two comments to make. In par. 7 at the bottom of page 164, in the specifications for the erection of steel railway bridges, I would like to suggest the propriety of making it 8 ft. from the nearest rail, in the case of the main tracks, and leaving it 6 ft. for other tracks.

Again, on the bottom of page 167, third sentence, which begins "while the contractor is actively engaged in the erection," that we should specify or leave space for writing who is to give the signal.

In the last sentence of the same paragraph toward the bottom, there should be some provision for defining the responsibility for the protection of movement against other trains.

Mr. W. G. Atwood (National Research Council):—It seems to me that in par. 1 that the definition of terms belongs in the contract and not in the specification. The Association has a contract form which contains definitions covering this same point, and that form was submitted to the legal departments of the roads and approved at the time the contract was adopted. I think either the definition in the contract form should be embodied in the specifications when it is to be used, or should be omitted from the specifications entirely, since the specifications become a part of the contract.

Chairman Selby:—The Committee does not desire to attempt to answer the comments that are raised at this time. They will be considered by the Committee, and we are glad to get them. I may say, however, as to Mr. Atwood's point, that the same question may be raised as to a number of other clauses in these specifications. The attempt has been made to eliminate from the specifications things that are properly subjects for the contract form, but it has not been possible in every case, and the Committee recognizes that there are some clauses that are duplications of what may properly appear in the contract form, but we concluded that there would be no harm in a repetition, and maybe some good in calling attention to those phases in the specifications.

Mr. Albert Reichmann (American Bridge Company):—I would like to say regarding definitions in the specifications that the specifications are distributed quite extensively to employees executing the contracts; whereas the contract itself has a limited distribution, and I therefore think it would be advisable to have these definitions in the specifications.

Mr. G. H. Gilbert (Southern):—Article 25, page 168, under "Work Train Service," requires the contractor, before he enters into a contract, to state how many days work train service will be necessary for his needs. In other words, he must name a fixed money consideration for work train service. It seems to me that the amount of work train service should be definite only as to the kind or class of work to be performed. Thus the amount of work train service would be indefinite as to cost to the railway company, but definite as to extent of bridge work to be performed.

Chairman Selby:—I move that the specifications for the erection of steel railway bridges be received as information and published in the Proceedings.

(The motion was carried.)

The next subject, No. 3, is Specifications for Movable Railway Bridges. In submitting these specifications I would like to read the Foreword on page 169.

The Committee has a few slight changes to submit.

Article 314: Correct typographical error in second formula, changing numerator of the fraction from 25,000 to 250,000.

Article 315: After "For rollers in motion," add: (d not to exceed 64 in.)" After "For rollers at rest," add: "(d not to exceed 28 in.)"

Article 415, last par. (at top of page 187), second line, change "125 d" to "$3{,}200 \sqrt{d}$"; fourth line, change "7,500 lb." to "13,000 lb."; at end of par. add: "The loads considered in this paragraph shall include 20 per cent. impact as provided in Article 302."

After the specifications were published in the Bulletin, there was some criticism received of the allowable bearing pressure per linear inch on the rolling elements of rolling bascule bridges. The Committee desires to make the following changes:

In Article 415, last par. (at the top of page 187), in the second line change "125 d" to "3,200 $\sqrt{d}$." In the fourth line change 7,500 lb. to 13,000 lb. At the end of paragraph add: "The loads considered in this paragraph shall include 20 per cent. impact as provided in Article 302." The sentence just read merely clears up what might be an uncertainty in the application of the provision for impact in Article 302. The other two changes are in the direction of more consistent unit stresses. These additions were decided on after a study of the experiments on rollers and experience with existing bridges. We found that the straight line formula given here is not susceptible of extension with safety beyond the limits of the experiments.

With the changes just read, in behalf of the Committee, I move the adoption of the specifications for movable railway bridges, and printing in the Manual.

The President: Are there any further remarks?

Mr. Reichmann:—I will say that we designed a 162 ft. double track bascule bridge for the Wabash Railway, at Detroit, according to those specifications and found them very satisfactory to work to.

The President:—This is a very conservative Committee. This was printed in the Proceedings two years ago to give you a chance to knock it out if you desired to. Do you approve of the report?

(Mr. Selby's motion was put to a vote and carried.)

Chairman Selby:—On subjects Nos. 4, 5 and 6, the Committee reports progress, and expects to make these three subjects the principal work for next year. They are all important subjects.

As to subjects 7 and 8, the Committee recommends their continuation. The work on column tests has been quiescent for several years owing to the inactivity in the Bureau of Standards. It is to be hoped that we can get some results later on. Electric welding of connections in steel structures has not progressed much and the Committee has not been able to get much reliable information bearing on that particular branch of the subject. On subjects Nos. 9 and 10, the Committee reports progress and recommends that those two subjects be combined and continued to next year. The Committee has nothing further to offer except the outline of work, which is up to the Board of Direction, I understand.

Mr. W. H. Courtenay (Louisville & Nashville):—I would like to inquire of the chairman of this Committee if there is any possibility of getting the government to adopt any rules for lighting bridges. I have had quite an extensive experience with that, and I have been unable to get them to adopt uniform rules on one system of railroad. A government officer in charge of one district will have different rules from the government officer in another district. Has any expression of opinion been obtained from the government authorities as to the feasibility of getting uniform rules for lighting bridges?

Chairman Selby:—Yes, sir; it was just that lack of uniformity that Mr. Courtenay speaks of that brought up this subject, and the chairman of the sub-committee, Mr. Rodenbaugh, has interviewed the Chief of Engineers and another government department head—I believe the head of the lighthouse board—and has received assurances that the recommendations of this Committee, if they are presented in concrete form, will receive favorable consideration. As we view it, all we have to do is to get a constructive recommendation that can be endorsed by the railroads concerned, and that will not conflict with the navigation interests, and we will be able to take a long step in the direction of uniformity in these respects.

Mr. G. A. Mountain (Canadian Railway Commission):—The Dominion Government has standard lighting of swing bridges, and I will be pleased to see that a copy of this standard will be sent to the Committee if the Committee can use it.

Mr. Frink:—Mr. President, the recent arrangement that has been concluded between the Secretary of Commerce, Mr. Hoover, and the American Engineering Standards Committee, I think will render it absolutely certain that some mutually satisfactory arrangement for lighting drawbridges can be arrived at, and if we can agree upon satisfactory uniform regulations, it will be carried through without much trouble. We all know that Secretary Hoover has very much at heart what he calls the simplification of industry, which is practically the same as standardization, and I think he would be very apt to take a hand in any point of that kind.

The President:—The Committee deserves the thanks of the Association. They have rendered splendid service, and they are dismissed with the thanks of the Association. (Applause.)

DISCUSSION ON STANDARDIZATION

(For Report, see pp. 225-228)

Mr. E. A. Frink (Seaboard Air Line) :—The report of this Committee is published in Bulletin 240 on page 225. The preliminary two pages I think it is not necessary for me to read. I know you have all read every word of it and appreciated it, but I will start at the bottom of page 227.

(Reading conclusions 1, 2, 3, 4 and 5—p. 227.)

These conclusions are entirely new matter. Nothing like them, as far as I know, has ever been presented to you before. They are recommendations that certain things be presented to the American Engineering Standards Committee for their action, and in order that you may know what that means, I would like to read a little description of what that Committee is, and what its procedure is.

You will note that the conclusions of your Committee this year are five in number and solely recommendations for presentation to the American Engineering Standards Committee. Before proceeding to the consideration of these conclusions, it is advisable to give you a concise idea of the meaning of the action requested.

The American Engineering Standards Committee, while beginning in January, 1917, did not hold a meeting until October 19, 1918, and it was not until 1919 that it really functioned. Considering the short time which has elapsed, its achievements are already considerable and offer great promise for the future.

This Committee is made up of representatives of twenty member bodies, some of them being groups, like the Fire Protection Group, which is composed of the Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters, the National Fire Protection Association and the Underwriters Laboratory, the balance being associations and Government departments, among which may be mentioned the American Electric Railway Association, the American Railway Association, the American Society for Testing Materials, Association of American Steel Manufacturers, the United States Departments of Agriculture, of Commerce, of the Interior, the Navy Department and the War Department. These member bodies represent twenty-eight organizations and have fifty-two members on the Main Committee, which meets four times per year. An Executive Committee, composed of one member for each member body, holds monthly meetings, except in July and August. So far, 17 standards have been approved, 17 are now up for approval, 79 projects are in various stages of progress, and engaged on these various projects are 160 co-operating bodies with 548 individuals as members of sectional committees.

The method of handling work is as follows:

The A. E. S. C. is not an initiating body and work on a project or proposed standard is undertaken only upon formal request from a responsible body and after the Committee has assured itself that the work should be undertaken. Usually this assurance is determined by a conference of representatives of all interested parties.

After it is decided that standardization is desirable, one or more existing bodies are requested or appointed to act as sponsors for the project, being intrusted with the duty of forming a sectional committee, that is, a committee to work out the details of the standard, the personnel of this committee being subject to approval by the American Engineering Standards Committee. This sectional committee works out the details and makes report to the Executive or Main Committee of the A. E. S. C., who, after all parties at interest are agreed on the proposed standard, adopt it as Tentative American Standard.

Therefore, if you approve the recommendation of your Committee to submit these various standards to the American Engineering Standards Committee, it simply means that each one of them will pass through so much of the above routine as may be necessary to assure the Engineering Standards Committee that the subject is in proper shape for adoption as Tentative American Standard.

The past year has been noteworthy for progress being made in standardization work in this country. The United States is far from being a leader in this work. There are now national standardization bodies in Austria, Belgium, Canada, Czecho-Slovakia, France, Germany, Great Britain, Holland, Italy, Japan, Norway, Sweden and Switzerland, making, with this country, fourteen in all. In Germany, progress has been most noteworthy and has been carried on with an intensity and on a scale not to be found in any other country, except Great Britain. It may be significant that America's two chief industrial competitors have made such progress in national industrial standardization. The German central organization was begun in 1917, really growing out of the efforts of the government to increase production and conserve resources during the war. In 1921, in addition to engineering societies, industrial organizations and government ministries, no less than 5,000 business firms were contributing members. The standards adopted are published in loose leaf form, making each sheet as nearly independent as possible, so that they may be used for working drawings. This plan, incidentally, is also followed by the Austrian, Dutch, Swedish and Swiss bodies. The standards may also be obtained printed on tracing paper for reproduction. In the four years since the inception of the movement, 144 approved standard sheets have been issued and 504 others are published as proposed standards. The central office staff has a membership of thirty-five, of whom seven are experienced engineers, and an idea as to the amount of business transacted is given by the fact that the average number of pieces of outgoing mail is 1,500 per day.

The British Engineering Standards Association, in 1920, had some 275 committees with over 1,370 members giving time and experience to the work. It has adopted and published a large number of standards, some of the most important being steel sections, rails, poles, automobile parts, rating rules for electrical machinery, details of the construction of ships and their machinery, etc.

It is apparent that practically the entire industrial world is very much alive to the importance of this question and is making substantial progress and achieving important results.

One of the most encouraging things about the American Engineering Standards Committee is the membership of five Departments of the United States Government. In addition to this, the Bureau of Standards acted as sponsor for seven projects, the Bureau of Mines for four, the Forest Service for two and the Public Health Service for one. The Bureau of Standards is officially represented on the sectional committees for twenty-two other projects. Dr. A. S. McAllister has been detailed by the Director of the Bureau as special representative in the work of the A. E. S. C., and is stationed in New York for constant co-operation with it. In July, 1921, the Secretary of War issued an order that the supply branches of the Army utilize in connection with their specifications, the standards that had been or may be adopted by the American Engineering Standards Committee. The Department of Labor now provides representatives of labor on all sectional committees dealing with safety codes. The various state commissions concerned with industrial safety matters are actively participating in this work. At a recent conference on proposed specifications for overhead crossings of wires and cables, which involves the National Electrical Safety Code of the Bureau of Standards, representatives of the public utilities or railroad commissions of Connecticut, Iowa, Minnesota, New York and Rhode Island were present and took part in the proceedings.

One of the chief developments, and the most recent, is a working arrangement with Secretary Hoover, who, as you may know, is very much interested in this work and has recently organized a Division of Simplified Practice, which, as far as I can see, is simply standardization under another name. He proposes, as I understand it, to eliminate unnecessary types and sizes in the whole industrial field, thus simplifying greatly the problem of manufacture and promoting mass production, which in his judgment is a necessity if we are to recover quickly from the effects of the recent world conflict. As this work overlapped the work of the American Engineering Standards Committee, a conference was held on February 25th, between Secretary Hoover in person and the chairman, Mr. A. W. Whitney, and past-chairman, Mr. A. A. Stevenson, of the American Engineering Standards Committee. At this conference it was agreed that at all future meetings of the Division of Simplified Practice an accredited representative of the Standards Committee would attend, and at all meetings of the Standards Committee, an accredited representative of Mr. Hoover would attend, if possible, the idea being that the two movements are to be co-ordinated so that duplication may be avoided and the agency best adapted may handle any particular question. Mr. Hoover has appointed Mr. W. A. Durgin, Chief, Simplified Practice Division, Department of Commerce, as his representative, and the American Engineering Standards Committee has appointed A. A. Stevenson, Vice-President of the Standard Steel Works Company, Philadelphia, Pa., Past-Chairman of the Committee, as their representative. As you know, the American Railway Association is now one of the member bodies of the American Engineering Standards Committee and has appointed the Chairman and Vice-Chairman of the Standardization Committee as its representative and alternate. The American Railway Engineering Association, being the Engineering Division of the A. R. A., furnishes representatives for sectional and other committees of the American Engineering Standards Committee, no less than fourteen of our members being at present engaged in this work. In addition to this, representatives from the Signal Section, the Mechanical Division and others are serving on appropriate sectional committees. There are many other things in prospect which will be of interest to this Association and concerning which we must make our opinion felt; for instance, the standardization of signal lights for highways and automobiles which may vitally affect highway crossings of railroads and in which we would be immediately interested. It is a matter of gratification that our present close contact with the American Engineering Standards Committee will give us advance notice of all such matters and enable us to obtain proper representation on the committees considering them.

Your Committee on Standardization is very much gratified at the present prospect of good progress along these lines. The field is large and the results to be obtained are correspondingly large, and we feel, as noted in our report, that every effort should be made to follow up in detail each avenue of progress which may open before us. At the last meeting of the Committee, held in New York City on November 29th, the Committee recommended to the Board of Direction that every committee of the Association be given as the second item in the order of work, the duty of recommending matter that should be submitted as a basis for standardization. We think its importance warrants such action and we hope that the Board of Direction and the Committee on Outline of Work will see fit to follow our recommendation.

In view of the fact that the working arrangement with the Department of Commerce was only concluded this month, the Conference having been held the 25th of February, it has been impossible for me to consult the members of the Standardization Committee about this matter, but I think that more assistance will be obtained from the American Engineering Standards Committee in the matter of standardization than in any other way that we might select. I therefore want to urge you all, if possible, to vote favorably on the Committee's recommendation to refer these five matters to the American Engineering Standards Committee for their action.

Mr. H. R. Safford (Chicago, Burlington & Quincy) :—I am thoroughly in accord with the Committee's recommendation, and the comment I make is merely upon a technicality, as to whether we should take the action contemplated, especially with reference to item No. 4, which says: "Railway lamps, as developed by the Committee on Signals and Interlocking, to be presented by that committee at the next convention." The point I want to raise is, can we at this time take action that places this matter before the American Engineering Standards Committee until it has been acted upon by the body from which it originated? This implies that that particular item is to be subjected to the action of the convention. That has not occurred, and I submit that this should have the approval of this convention.

Chairman Frink:—Answering Mr. Safford's question, I think we can, and for this reason. The procedure of the American Engineering Standards Committee is practically identical with the procedure which must be undertaken by one of our standing committees if they are to obtain or attain proper results of standardization. One of our standing committees develops a device or a design or a specification as near their ideal as they can. Then they consult other interested parties, manufacturers and other people, and make the necessary modifications to make that standard practical before it is presented to this convention. That is exactly the procedure of the American Engineering Standards Committee. I am going to propose after we dispose of these matters that the Board of Direction take just that action, and that after the matter has passed through that procedure with the American Engineering Standards Committee, it then comes back to this Association through its standing committee, or through its Committee on Standardization, is presented to the convention for action, either approval or disapproval, as they see fit. In other words, our submitting something to the American Engineering Standards Committee for their action does not in any way bind us to accept the results when they are through with it. We have perfect right to take those results, submit them to our convention, and approve or disapprove as we see fit.

Mr. Safford:—Is that true about those two last-mentioned items? Are we not taking action a little bit too soon? I do not think they should be submitted to the American Engineering Standards Committee until it has had the ratification of the convention.

Chairman Frink:—Our sending anything to the American Engineering Standards Committee does not signify that the Association has approved it at all. It simply means that the Association thinks that that particular thing should be standardized, and that we are willing to be sponsor for such standardization, but that we will not accept it unless it suits our convention after it is done.

Mr. J. J. Yates (Central Railroad of New Jersey):—I am a member of the American Engineering Standards Committee, which Committee is a clearing house for standards. The purpose is to take the specifications or designs, that are submitted, and consider them for standardization, but the Associations submitting them are held as sponsors. The Standards Committee in accepting a suggestion of this kind considers that the

Association in submitting them, has come to an agreement on this specification and is ready to back it. The Standards Committee, when they have an article or specification submitted in this manner ask other interests to act as sponsors and in appointing sectional committees they see to it that all who are interested are represented on these committees. It may be that the specification is sent back for changes, and that there are conferences, but there has to be full agreement before a specification is standardized. I really think we are a little premature in submitting a specification now that has not had the approval of our Association.

Mr. C. A. Morse (Chicago, Rock Island & Pacific) :—I cannot help but agree with the last speaker. It seems to me that in the 23 years existence of this Association, we ought to be able to have five things that we can present to the Standardization Association that have been approved by this Association, and not have two out of the five that are put up that have not been passed upon by the convention.

Chairman Frink :—I would like to say in answer to what Mr. Morse said, that these five things were proposed by appropriate standing committees, and it was the desire of the Standing Committee, as expressed to your Committee on Standardization, that they be reported to the convention in this way.

In regard to this question of recommending to the American Engineering Standards Committee work that has not had the approval of the convention, if you recommend to the American Engineering Standards Committee something that has been approved by the convention, then most positively it will be modified. It is almost inconceivable that anything that we may get up, no matter how carefully it is done, will suit all the different interests who are on the sectional committees of the American Engineering Standards Committee. On that sectional committee will be 1, 2, 3, 4, or maybe more representatives of this Association. If a subject has been approved by this convention, they will be placed in the unenviable position of being asked to agree to a modification of something which the convention has approved. Personally, I believe that it would be better if these matters were presented to the Engineering Standards Committee before they are approved by the convention rather than after. We have two strings. One string in the Sectional Committee, our representatives, who can keep in touch with the situation and see that our views are met. We have a string after the Engineering Standards Committee have completed their work, in that before it becomes our standard it has to pass this convention, it has to be approved by it. I cannot see the slightest danger to be apprehended from that course of action.

Mr. Morse :—It seems to me a good deal like the District Engineer taking up something with the Vice-President over the Chief Engineer's head.

Chairman Frink :—That has been done, hasn't it?

Mr. Morse :—Yes, sir.

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Mr. W. M. Camp (Railway Review):—Will Mr. Frink, the chairman of the Committee, enlighten us a little further? If something which has been approved by this convention and is in our Manual were presented to the American Engineering Standards Committee, and were then modified in some respect, then what? Will it come back to the A. R. E. A. to be modified again to conform to the American Engineering Standards Committee's ideas? How about that?

Chairman Frink:—It will come back to us, but not to be modified, except as regards ourselves. In other words, the Engineering Standards Committee will be the court of last resort as regards the United States in general, but we are our own court of last resort in regard to our own practice. Anything that the Engineering Standards Committee may approve will be put out as the American standard, and we will adopt it or not as we see fit. We are not obligated to in any way.

Mr. Camp:—I would like to know specifically in regard to these two sections, 4 and 5, that this Association has not yet passed upon. Suppose that they go before the American Engineering Standards Committee and by chance get through, then will they come up before this convention? Suppose they are amended somewhat, then in that case A. R. E. A.'s recommendation would not harmonize with the Engineering Standards Committee.

Chairman Frink:—No, sir; we would be placed in the position that we would be asking for a special article, which is just exactly one of the things that the Standardization Committee hopes to avoid. It is our idea that if these articles 4 and 5 are referred to the American Engineering Standards Committee it would be better if they were not adopted by this convention—it would be better to wait the action of the American Engineering Standards Committee to get a completed design or specification satisfactory to all interests. Then if we find that that design is suitable to our use, to adopt it and print it in the Manual of Recommended Practice.

Mr. C. R. Harte (Connecticut Company):—May I ask Mr. Frink if it is not the case that in the American Engineering Standards Committee there must be an absolute acceptance on the part of the sponsor before the matter is accepted by the American Engineering Standards Committee. It so happens that I am a member of the American Electric Railway Association, and we have had before the American Engineering Standards Committee several matters for standardization. A subject for standardization may be submitted by any one; the Committee then calls a conference, at which are represented all bodies in any way interested, to decide if it is desirable to develop the proposed standard, and if the development seems desirable, a sponsor or joint sponsors are appointed by the Committee, and the sponsors then organize a sectional committee, on which there must be representatives of the manufacturers, of the consumers, and of the independent interests, in such proportion that no one will have a majority. The Sectional Committee prepares the proposed standard and submits it to the sponsor for approval, but I do not understand that the matter can go to the Main Committee itself until the sponsor is entirely satisfied and approves it. That in itself would seem to preclude any action by the sponsor after the American Engineering Standards Committee has itself taken action.

However, there are two classes of matters that come up. There are those matters which an Association or committee brings forward, in which it itself is the chief interested party. If it can be shown that the matter is already an accepted standard, that it is in general use, that there is no serious objection to it, it can be adopted by the American Engineering Standards Committee as an American standard, without submission to a Sectional Committee. If, however, the matter is one in which there is conflict, there must be an adjustment between the parties in interest, and this adjustment must be complete before it can be accepted as the design. I think the fundamental proposition of the American Engineering Standards Committee is that there shall be an agreement before the standard is promulgated. Isn't that the case, Mr. Frink?

Chairman Frink:—You were present at our last meeting and you very well remember the way that we handled the matter of overhead crossings. I think you have got a little incorrect idea. There must be an absolute agreement between all interests, as far as represented on the sectional committee. That does not necessarily mean that the entire main body back of the representatives on the sectional committee must also agree. For instance, if there is a sectional committee this body may have three members, and while those three members must absolutely agree on the detail before it will be approved by the Engineering Standards Committee, that does not necessarily mean that the entire A. R. E. A. agrees on it without going into convention. That is the only way they could go. They are representatives of the A. R. E. A. and as such must act according to their best judgment, and get the device or specification lined up in a way that they think will suit this Association, but necessarily they cannot guarantee that this Association will absolutely approve it. That is a matter for the Association.

Mr. Harte:—I am afraid that I have not quite made myself clear. As I understand it, the sponsor must approve before the American Engineering Standards Committee will take action. As I understand it the American Engineering Standards Committee makes no attempt whatever to pass on the technical merits of a specification. I do not consider that the American Engineering Standards Committee has the right to promulgate any specification as an American standard until it has been referred back to the sponsor for definite action by that society or association, or whatever it may be.

Chairman Frink:—As far as I know there is no referring back to the sponsor. That matter is decided by the representative of the sponsor on the Standards Committee. You may remember that at the last meeting of the committee there was a disposition on the part of some members to refer back to the sponsor the arrangement with the Department of Commerce but the matter was decided right there by the representatives.

Mr. G. A. Mountain (Canadian Railway Commission) :—I am a member of the Canadian Engineering Standards Association, and also a member of two sub-committees. I presume the American Standards Association and the Canadian are very much the same. Ours is attached to the Department of Trade and Commerce. After they have finally passed on a standard of any particular subject, it does not go back to any other Association for their approval. That is final. It has to be acted upon.

Chairman Frink:—I do not want you to misunderstand what I said. I said after the American Engineering Standards Committee passed on a matter it would come back to this Association, but it would simply come back to this Association for its action as regards itself. Its action will thereafter affect none of the members of the American Engineering Standards Committee at all. They pass on it and adopt a device or design as a tentative American standard to be tried out for a certain length of time to determine whether it is all right or not. After that has been done, it would come back to this Association for determination as to whether they would adopt it as their standard or not.

Mr. Morse:—In looking over these resolutions, I understand that 4 is part of the report of the Committee on Signals and Interlocking, that is to be presented to this convention. Five is part of the report of the Committee on Electricity, and it is to be presented to this convention. It seems to me you could pass these resolutions as Mr. Frink wants with the proviso that if the convention approved them, when they are reported by the various committees, they are all right; if not, they are to be omitted.

Chairman Frink:—The Committee will accept that suggestion, I am sure. I am sure I will.

Mr. Safford:—This raises another point. It seems to me that we might establish a procedure here which will take care of the situation in the future without delay. Is there any reason why this Committee on Standardization should not automatically have authority to place before the American Standards Committee any recommendation that this Association has adopted? In other words, I don't think it is necessary for this Committee to come before us at subsequent meetings and ask for authority for anything that has gone into the Manual and has received our approval. I think that they ought to automatically present them as they may see fit, in the development of the whole question with the other members of the Standardization Committee if they do not put before that body anything that we ourselves have not passed on. Then as to these two items that are coming up at this meeting, if they are ratified and approved, the Committee may then take such action as they see fit.

The President:—We have just been admitted into this society, we have never yet gone into detail as to how it should be done, whether it should be done by approval of the convention, approval of the Board of Direction or the Committee itself should go alone. That has never been brought up, but in order to give the matter a start, a Committee from the convention can approve these if they see fit to do so, and then the Board of Direction can decide as to the future course to take.

Mr. Safford :—I believe that the recommendation as to any device will carry much more weight with the Standardization Committee if it has the endorsement of this meeting. I think it obviates any possible chance of confusion, as this discussion develops.

The President :—Are you ready for the question on the motion as amended?

(The amendment prevailed.)

Chairman Frink :—The rest of the report of this Committee is as to recommendations for future work and I will not go into that, because that is a matter for the Board of Direction. However, since the entrance of the American Railway Engineering Association as a member of the American Engineering Standards Committee, and my being on it with the position of representative of that Committee, which honor I assure you I feel very deeply—another question has come up about the method of handling projects with the American Engineering Standards Committee. I have had no opportunity to consult my Committee at all, but I have a motion to make for the consideration of the convention which bears on that subject.

Some years ago when I first became interested in standardization I had a very interesting day dream of this Association conducting such a movement, not only inspiring it, but actually carrying out the work. It was a large order. I think perhaps some of my associates thought it was too large for our Association to undertake, but I believe that this Association will grow in the size required to handle any project we may undertake. However, that is now a dead issue. It was inevitable that at a certain stage of industrial progress the world must undertake standardization. That the movement began in other countries means that their needs were greater than ours. But it is now well under way, its progress is bound to continue, and our main consideration should be to guide it along proper lines as far as we may.

There are two points of primary importance, first to see that articles of interest to the railroads, and which can advantageously be standardized, are put in line for action. Second, and this is perhaps the most important, to see that the work is carried on along conservative lines and does not go too far. Standardization gone mad would be more harmful than none. Never has the prospect been so favorable as now. The American Engineering Standards Committee is a thoroughly representative body, with quite as much government backing as is at all desirable in this country. It is well organized and has set up a well devised system of handling its work that practically insures the agreement of all parties at interest in the preparation of a standard before it is adopted. Therefore, as we have a permanent member of the Committee to care for our interests, to see that we are informed of all projects, and that our Association and other divisions of the A. R. A. have proper representation, it behooves us to support the work of the Committee in all possible ways, and to make full use of its machinery in furthering our own stand. The American Engineering Standards Committee has a great deal of work to do. They have to maintain a considerable force at headquarters in addition to a paid secretary, and like all associations in the beginning they are short of funds. It would only cost this Association $500 a year to obtain another membership, which would entitle them to another member of the Engineering Standards Committee, and I sincerely hope that they may see fit to do that.

However, the main point that I want to talk to you about today is the method of handling projects with the Engineering Standards Committee, and in order to bring the matter to a head, I want to offer this motion:

"Resolved, That whenever a project prepared for or approved by the proper standing committee is reported to the Board of Direction of the Association by our Committee of Standardization, with a recommendation for presentation to the American Engineering Standards Committee, said Board of Direction be and is hereby authorized to, in its discretion, present such project to said American Engineering Standards Committee with a request for action, this Association to be a sponsor for such project."

That covers the point I think made by Mr. Safford a little while ago, but instead of making your Standardization Committee the direct intermediary with the Engineering Standards Committee, it makes the Board of Direction the intermediary, and I think that is not only more conservative but more proper. I hope that you will see fit to pass this resolution.

Mr. Chas. S. Churchill (Norfolk & Western):—It seems to me that this motion is all right with one proviso, and that is that this committee shall act in conjunction with this Association and the American Railway Association.

Chairman Frink:—I thought, Mr. Churchill, inasmuch as the Board of Direction would take the action, and inasmuch as our Secretary is also Secretary of the Engineering division of the A. R. A., it was sufficiently safeguarded.

Mr. F. J. Stimson (Pennsylvania):—Yes, but I think it ought to be made plain to the A. R. A., and I move that the resolution be amended in such a way as to provide that one year after the adoption of the A. R. E. A. recommended practice, that the Board of Direction, etc.

The point is this: It does not seem to me we want to go on record at this time as putting it in the hands of the Standardization Committee to recommend to the Board of Direction, and the Board of Direction to take action with the American Engineering Standards Committee before the matter has come before the convention. As I understand the meaning of the resolution as presented it means that a committee may formulate a report, the Standardization Committee may take favorable action on it, the Board of Direction may act favorably on it, and then may go to this Standards Committee without coming before the convention. I believe that that is not proper procedure, and I believe that even after having been published it ought to have one year in which to be under fire, in order that weaknesses may be discovered and revisions may be made. Therefore, I think it is very proper that no matters should be taken to the American Engineering Standards Committee until the A. R. E. A. has passed upon it.

Chairman Frink:—Mr. President, I hope that amendment will not prevail. It seems to me there is a misconception as to what this procedure of the American Engineering Standards Committee means. The Engineering Standards Committee is not a body to which you submit a perfect article for them to put their stamp on at all. The American Engineering Standards Committee is just like the A. R. E. A. in a way, that is, it takes in incomplete articles, it takes in unfinished specifications and provides the machinery whereby those things are brought to a final condition to which all parties in interest may agree.

As I see it, it is not at all necessary that we even have anything on paper about an article before we submit it to them. We can go to them and say: "I think this ought to be standardized. Take it up and see." Their representatives will get together and work out a design that suits everybody, if it is possible to do it.

The President:—Well, gentlemen, let us get this cleared up here.

(Mr. Stimson's amendment was put to vote and carried, and following which the original motion as amended was put to a vote and carried.)

Mr. H. R. Safford:—I am interested in the Committee's work. It was organized as a new venture, and with some doubt as to how efficiently it could perform its function, but Mr. Frink, with his experience, has gotten the work of the Committee under way, and I want to urge the members of the Association to do all they can to help the Committee. I think it has had a remarkably good start.

Mr. W. M. Camp:—I understand that this motion nullifies what we did this morning about the conference between the Track Committee and the Ballast Committee.

The President:—I think so.

Mr. J. L. Campbell:—I want to supplement what Mr. Safford has said about the Standardization Committee. It appears to be getting into its stride and will be an instrument of great value to this Association. I am sure I voice the sentiment of the members of the Association in saying we are back of this Committee.

Mr. W. H. Hoyt (Duluth, Missabe & Northern):—There seems to be a lack of clear understanding of the processes to be followed, in adopting or presenting for adoption, the question of standards as between the American Engineering Standards Committee, and the American Railway Engineering Association.

I would like to suggest that the Board of Direction request the Standardization Committee to outline a plan of action, or co-operation, as you might call it, as between the American Engineering Standards Committee and the American Railway Engineering Association, and present such a plan of action in the Bulletin previous to our next meeting, so that the members of the Association may have a clear understanding of just what form of procedure would be satisfactory and work out to the best advantage of the Association in adopting standards.

I think we are more or less at sea in regard to the method of procedure. If such a report was made, it might elucidate matters, and make them clearer to all of our members, and the Committee itself, as to what proper procedure might be. If that were done next year we might adopt some proper method of operation between the two organizations.

Chairman Frink:—I want to be sure that you all understand the meaning of the action you took on the last motion. It means, first, that you are making your standing committees do a lot of unnecessary work which could be done by the American Engineering Standards Committee, and it means, secondly, that you have injected two or three years' delay in the final consummation of any matter, or final standardization which is also unnecessary.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—The Chair, in stating the motion to amend the original motion, left out the twelve months clause moved by the gentleman who made the motion to amend. I voted in the affirmative because the twelve months' clause was left out.

Chairman Frink:—The reason it means what I state is because the procedure our Committee will go through is identical with the procedure of the American Engineering Standards Committee. Therefore, if we could get them to do the work, and save the work of our own committees, it would expedite matters very much.

Your Board of Direction or Standardization Committee can present nothing to the American Engineering Standards Committee, except as this convention has approved of the same, and the convention meets once a year, and we must wait until the convention meets before anything can be put up before the American Engineering Standards Committee.

There is more than that. I do not think there is much doubt that it will take a Standing or Special Committee much longer to bring a project to the point of adoption than it would take the American Engineering Standards Committee to do the same thing. While this Association is large and powerful, the American Engineering Standards Committee is larger and more powerful. It has greater interests behind it, and can pull more strings for action, and has the merit of getting all interests together to work on the standards at the same time, whereas our committees must map out the work before they can get the other interests in a position where they can co-operate with them.

Our work is carried out by busy men, men who have all the work they can do for their own companies, and they have not the time to carry out the project with the promptness and energy that the sectional committees of the American Engineering Standards Committee can put on it.

Mr. J. L. Campbell (El Paso & Southwestern) :—That is true of new work and future assignments to this Committee, but the Manual is already of considerable volume and the Standardization Committee can begin handling those matters on which the Association has already acted and included in the Manual. I do not understand that the hands of this Committee will be tied until there is future action of this Association.

The President:—If there is no further discussion, the Committee is dismissed with the thanks of the Association.

Mr. Frink:—After the session on Tuesday afternoon a number of members of this Association have indicated to me in conversation that they did not understand the situation in regard to the American Engineering Standards Committee. I think it well to clear up the situation. In the first place, to give you an idea of the work of the A.E.S.C., I would like to say that it does not initiate work. It does no constructive work in the formation of standards. It is simply in effect a clearing house, an executive body, that considers forms of standards submitted to it by interested bodies. The means by which it does this are as follows:

The way in which a project comes to the A.E.S.C. is by the recommendation of some responsible party who is interested in the formation of the standard—maybe a manufacturer, or an association, or an engineering society, or anybody who is responsible and has an interest in the matter. They apply to the A.E.S.C. for action in formulating a standard. If the applicant is judged responsible, the committee surveys the entire situation as far as it can, gets the names of all parties at interest in the matter, sometimes, not always, summons a conference of those interested to discuss the matter and makes a report as to whether the standardization of the subject is desirable. If it is found that it is desirable, then one or more organizations or responsible bodies are appointed sponsors, so-called, for handling that subject. The definition of a sponsor is laid down in the rules of procedure of the A.E.S.C. as follows:

> "A sponsor is a coöperating body designated by the Main Committee, responsible for any standard or group of standards, presented by a sectional committee."

That simply means that the sponsor is simply charged with the duty of seeing that a standard is developed, seeing that it is right, or standing behind it in any way that is necessary.

The means whereby this standard is developed is the sectional committee, which is virtually the same as your Standing Committees. The personnel of the committee is reported by the sponsor or sponsors to the A.E.S.C. If the A.E.S.C. finds that the sectional committee is truly representative of all the parties at interest, they indicate that the work may proceed, and then the sectional committee gets to work and discusses all the details of the proposition, and whether they agree or not on the final form which the report should take, they report the result of their work to the A.E.S.C. That committee considers the results, and in order to approve the work as a tentative standard, it must be sent out by letter-ballot to all the members of the A.E.S.C.

In their procedure there is nothing that binds the sponsor to put the weight of its responsibility behind the standards. It is simply a means by which the sectional committee is to formulate the standard and get it in shape for action.

The reason I made the motion Tuesday afternoon is that last year the Standardization Committee proposed some 42 projects to the Board of Direction for action by the standing committees for prospective standardization. They never, I believe, have been acted on.

You can see from what I have said that there is no necessity for any organization which desires to have standardization work done to get the standard into a finished condition. It can send it to the A.E.S.C. and have it go through their procedure, with the idea of simplifying the matter, so that the number of points of contact would be reduced to a minimum. I repeat, it would not be necessary to get the standards into shape entirely satisfactory to you. You would save time and labor by getting the A.E.S.C. to do the entire work for you, and after it is done you do not need to accept it as recommended practice, unless you see fit to do so.

Mr. C. A. Morse (Chicago, Rock Island & Pacific):—I think the matter that came up with regard to our relation with the A.E.S.C. has run down to a misunderstanding. Our Committee on Standardization is rather misnamed, in my opinion. It is really a Committee on Coördination. The Constitution of this Association provides for formulating recommended practice. I do not think in any place it mentions anything about standardization. I think in taking a membership in this A.E.S.C. it is the duty of our representative on that committee to see that the work of the committee does not interfere with good practice on the railroad, rather than to present things from the railroads for standardization. Perhaps while I am a little extreme on this subject of standardization, I do not think that is what the Association stands for. I think it is a misapprehension on the part of our representative on the Standardization Committee wanting to present matters from this Association to them.

Mr. J. L. Campbell (El Paso & Southwestern):—I move that the relation of the American Railway Engineering Association to the American Engineering Standards Committee be referred to the Board of Direction with power to act.

(Motion carried.)

Mr. W. D. Faucette (Seaboard Air Line):—I understand the Chairman of the Committee desires not to be bound when he goes to the Standards Committee, but to have some flexible latitude. We cannot create any hard and fast rule with regard to the approval of standards. What we desire is that the interests of the Association will be safeguarded. I think the Chairman wants a little latitude and flexibility, and not to be bound to put up for standardization only the standards approved by the Association. The personnel of this Committee is such as I feel we can trust them fully not to complicate our Association in any matter it is handling for "standardization."

Mr. Edwin F. Wendt:—I think that Mr. Campbell's motion is very apropos, and in my opinion this question should be referred to the Board of Direction. The program on pages 2, 3 and 4 contains the general rules for conducting the work of the Association in respect to our committee reports and these should be followed until they are changed by appropriate action.

DISCUSSION ON SIGNALS AND INTERLOCKING

(For Report, see pp. 229-231.)

Mr. W. J. Eck (Southern) :—The material which the Committee is reporting is submitted as information.

(Mr. Eck then outlined the subjects assigned to the Committee.)

Mr. C. E. Lindsay (New York Central) :—What are the recommendations on the subject of railway lamps?

Chairman Eck :—At the meeting of the Committee on Standardization, where the subject of railway lamps was discussed, the Chairman of the Committee on Signals and Interlocking presented the series of lamps which had heretofore been adopted by the Signal Section, A. R. A. Since that meeting, however, one of the lamps has been revised. On account of the proposed revision I did not think the series was in shape to present today.

Mr. George A. Mountain (Canadian Railway Commission) :—Has the Committee considered the question of eliminating guard rails at interlocking crossings? The matter has been brought to my attention, and we have not any views one way or the other. I always look with considerable respect upon any recommendation made by the committees of this Association, and I would like to get the views of the present Committee on that subject.

Chairman Eck :—I have been a member of the Committee for many years, and do not recall that the subject has been discussed. If the question is referred to us by the Board, we will be glad, indeed, to consider that subject. I move that the report of the Committee be accepted as information.

(Motion carried.)

The President :—The Committee is excused with the thanks of the Association.

DISCUSSION ON TIES

(For Report, see pp. 233-262.)

Mr. W. A. Clark (Duluth & Iron Range):—As stated by the Standardization Committee, this Committee has represented the Association in a conference on the unification of tie specifications under the auspices of the American Engineering Standards Committee.

Subject 2 was combined with Subject 5, as they were closely connected, and I will ask Mr. Burton, Chairman of the Sub-Committee handling those subjects, to present the report.

Mr. W. J. Burton (Missouri Pacific):—These subjects were referred to the Committee last year, and the Committee, after study of what statistics were available in printed form, decided it would be necessary or at least desirable to solicit data, supplemented by opinions, from as many roads as possible. Such material was collected last year and was published. However, it was received so late in the year as to make it impossible to analyze it or draw any conclusions from it, and the report this year is an attempt to make use of the information which was received and presented to the convention last year. The answer to both questions is entirely dependent on one particular factor—the life of the tie, that is, before the proper answer can be given, we must know the life of the tie of the particular kind, based on the most reliable data which the Committee can secure. The answer for any particular location or particular condition depends upon knowledge of results secured elsewhere.

The Committee has found, as has everyone else who has gone into the subject, that the data available is not satisfactory for application in specific cases. Our tie statistics, generally, are more or less complete as to the conditions of the treatment of the tie, and the details of just what the tie was to start with, but they are not at all satisfactory as to the conditions of use. The Committee feels that the life of a tie is fully as dependent on where and how it is used, as on what it was to start with.

The greatest difficulty lies in comparing traffic on different railroads in different parts of the country, and in comparing climates on different roads in different parts of the country. We have in the past attempted to obtain these comparisons strictly by the number of years of life reported. But what is reported as heavy traffic on one road may be very light traffic on another road, and as for climate, even though a road may be in a territory in which the general climatic conditions are favorable, the local conditions may be such, as regards producing decay, that is not favorable to long life in the ties. In some places the local conditions are different from those of the surrounding country.

With these considerations in mind, the Committee is recommending the use of a standard test tie as a means of avoiding the difficulties of comparison between different parts of the country, the idea being that the standard test tie used in test installations will serve as a sort of thermometer to measure the climate, and also to measure the traffic. We may have a climate in which the standard tie will resist decay for six years; the six years will define the climate, and then there will be another climate where the standard tie will resist decay for eight years, etc. We intend to use the standard tie as a yardstick, not only to measure the climate, but also the traffic, and to use the results obtained with the test tie as a standard for comparing results from other kinds of ties. The Committee is recommending that for the standard test tie, a certain particular tie shall be designated.

The results of the data secured by the Committee are tabulated, beginning with page 239. The table on page 239 is made up from the returns obtained in last year's report, and we have eliminated from consideration all reports of ties which failed largely through mechanical wear; in other words, we are attempting to get at the relative resistance to decay of untreated timber. The results are averaged up in the fifth column, taking white oak as 100. The average life reported throughout the country for the white oak ties, untreated, is slightly over eight years. The table on page 239 may be said to represent the relative resistance to decay of untreated timber, as determined from the data in the hands of the Committee.

As a means of comparing the resistance to mechanical wear of different ties, the Committee has given considerable consideration to various formulae in which the physical properties of timber are taken into account, weighed, etc., but has come to the conclusion that the data we have, considering the relative crudeness of the whole subject, does not warrant such refinement. The Committee believe that satisfactory results can be obtained by considering the specific gravity of the timber as the measure of relative strength.

The tie is quite different from most parts of the railroad as regards design. The shape of the tie, the size of the tie, and the amount of timber contained in it remain substantially constant throughout its life, but the quality of the material varies from new to decayed. With most other parts of a railroad, the physical characteristics of the material remain nearly constant (this statement does not apply unqualifiedly with all timber), but ties are subject to much more severe decay conditions than any other part of the structure of the road.

The table on page 240 was prepared from the tabulation in Bulletin 556 of the Department of Agriculture (Forest Service), which gives the results of physical tests of various woods, and Table II is intended to justify the use of the specific gravity as the measure of mechanical strength. The mechanical life of the tie may be considered to be dependent upon how much reserve strength it has to start with. When the tie is decayed it has no strength left. It fails because its strength is then insufficient, and the Committee feels justified in using specific gravity as the measure of mechanical strength, based on this table. The data is also shown by Diagrams A and B, particularly Diagram B.

This diagram indicates that the modulus of rupture, which, for any particular cross-section of the tie, may be considered as the measure of the beam strength of the tie, varies according to the specific gravity.

The Committee considers the beam strength as fundamental in tie design, because if the beam strength is insufficient, there is no remedy. If it is not strong enough as a beam we cannot use it. If it is deficient in crushing strength across the grain we can use larger tie plates. If it is defective in spike holding power, we can modify this by the design of the fastenings. The beam strength is essential, and we consider the modulus of rupture the most important physical characteristic of tie timber.

Table III on page 242 is a combination of the decay charactertistics of various timbers as shown in Table I, and the mechanical characteristics as shown in Table II. Table III is perhaps not easily understood at the first glance, and the Committee itself has had considerable discussion over it.

The headings of the columns under the general headings of "Decay Failures" which read "Climatic Conditions Such that Under Light Traffic White Oak Ties Fail by Decay" might be headed "Measure of the Climate." We have used six years, eight years, and ten years' life of white oak as the basis for this table, these ties being used under very light traffic.

For instance, in column 2, we start out with the white oak tie at 100, corresponding to eight years. The other woods in column 2 are listed in proportion to the results given in column 5 of Table I, except that the values have been slightly modified.

The values for the several kinds of timber in columns 4 to 9 are based on the specific gravities of the various timbers, but starting with the white oak at 50, corresponding to a life of four years, which life the Committee considered about the shortest average life where mechanical wear is the determining factor.

Columns 10, 11 and 12 are headed in a manner similar to columns 1, 2 and 3, or in other words, column 12 means that the ties are subjected to a climatic condition such that a white oak tie under very light traffic will fail in ten years. It does not mean that the white oak ties under the particular traffic fail in that time, but it is such a climatic condition as would cause the white oak ties to decay in ten years if allowed to decay and that the actual failures are partly decay and partly mechanical. The table is prepared as though the failures are fifty-fifty, decay and mechanical. We do not know of any way of ascertaining that the tie fails three-quarters by mechanical wear, and one-quarter owing to climatic conditions, or any other certain proportion. The best that can be said is that it fails both by mechanical wear and by decay.

The Committee submits some examples as to how the data in Table III, together with the diagrams given on pages 245 and 246, may be applied. These two diagrams were published by the Committee a year or so ago in connection with a report to the A. R. A. on substitute ties, and are merely diagramatic representations of the compound interest formula, which formula was recommended for computing the annual cost of ties. The diagrams on pages 245 and 246 are for ties not having a salvage value, and they would not apply to substitute or other ties having a salvage value.

The recommendations to the Committee are given on page 238.

(Mr. Burton read the recommendations referred to.)

Chairman Clark:—I move that the recommendations be adopted.

Mr. V. K. Hendricks:—It seems to me that by considering the relation of the average life of ties to the percentage of renewals, the Committee could get much valuable information as to tie-life from a study of the actual annual renewals on the different railroads, going into more detail than has ordinarily been the case. It would be very desirable to make such an investigation, although the subject is a large one to go into. I have been studying a paper by Mabel E. Thorne, Statistician of the Forest Products Laboratory, which was presented to the American Wood Preservers' Association, in January, 1918, the results of which could be applied to good advantage in many cases.

Mr. W. H. Courtenay (Louisville & Nashville):—This matter of getting reliable information about ties is one of great difficulty. The Committee's own table on page 242, appears to me to indicate that. I understand column 1, in situations where a white oak tie will last six years, that cypress tie lasted 5.4 years. That is certainly not true of certain parts of our country. A white oak tie produced in our territory near the Gulf Coast will not last there more than six years, ordinarily.

I doubt if the average life will be as much as six years.. I have actually seen cypress ties that were laid over 30 years ago; there could be no doubt about the age of the ties, as they showed the change of gauge made in 1886, and that was conclusive proof. Under ordinary traffic a so-called black, red or yellow cypress tie will last more than 25 years. I have seen cypress ties which have been in service much more than thirty years. They will not stand under heavy traffic. The life of cypress ties under heavy traffic is wholly determined by mechanical wear. Even though ample sized tie plates are put in, the traffic will drive them down. I mention that to show the extreme difficulty of getting correct information about ties.

Years ago the Louisville & Nashville used on some divisions one species of tie exclusively. We obtained reliable information then, and were in the habit of computing every year the average renewals per mile in periods of four, eight and sixteen years immediately preceding the date of making the computation, and determining whether the superintendents requested too many or too few ties, and in forming our judgment in that regard we relied on these averages, but since the United States Railroad Administration began to use almost any and all kinds of ties, the changes have been so great that the matter has been greatly complicated.

As to the propriety of using a 6-inch tie for making a test, I doubt it.

Mr. Burton:—Mr. Courtenay has spoken of the difficulty of getting satisfactory data; the Committee fully appreciates this fact. We would be very glad to receive data from the L. & N. or any other railroad which has not furnished it. Last year we tried to obtain information about the cypress ties on the L. & N., but did not receive reply containing it. We realize that this whole subject is one which, with our present knowledge, cannot be treated as though mathematically exact.

As regards the comparison between white oak and cypress in column 1, the white oak is shown as 75, which corresponds to six years. The cypress is shown as 90, which corresponds to 7.2 years. The interval may not be large enough between the white oak and cypress, but the 90 is arrived at from the returns which the Committee received last year, which included, in the case of cypress, returns from fifteen or twenty roads.

As regards the choice between the six-inch and the seven-inch test ties, the Committee has had considerable discussion. At first it considered the possible use of both the 6 and the 7-inch ties, but this seemed to defeat the purpose of the standard, and we finally decided on the 6-inch 8-foot tie, because of its shorter life as compared with the 7-inch tie, and because therefore we will obtain results more quickly. A further consideration was that the 6-inch tie is more largely used, as shown by the returns to the Committee, and it is, perhaps, the tie which is most largely used, taking the country as a whole.

The standard size, particularly in the West and Middle West, has been 6-inch by 8-inch by 8 feet. The Committee felt, while it was not the best tie, perhaps it might be the best we could select for a standard test tie.

Mr. Courtenay:—I can furnish reliable data on ties laid years ago. Our lines extend from the Ohio and the Mississippi River to New Orleans. On the Gulf Coast, between Mobile and New Orleans, it is hardly worth while to put a white oak tie in. It is hardly worth while putting in a long leaf yellow pine tie unless it is treated, but the cypress tie will give long life in that section.

It is a difficult thing to do, and it will cost a tremendous amount of money to give precise figures as to the life of ties. Since we have been treating ties with creosote oil and chloride of zinc, and distributing them all over the system, mostly due to the great difficulty of getting ties in the last few years, we had a number of them taken out, but we have no record what ties were taken out, and I think it would be a matter of very great value to the railroad if we could get accurate statistics about the life of ties on our own road, and about the only way to do it is to keep a life record of each individual tie, which is a rather large job, and particularly as you will have to rely upon the foreman to do that. Foremen's talents do not lie in that direction, and it is practically impossible today to get the data on the life of the different kinds of ties. Anyone who has used ties extensively knows perfectly well that white oak will last longer than any other type of tie in some territories. The same thing applies to other species, and cypress is the tie which gives the longest life in the extreme South under light traffic.

A good deal has been said about standardization of specifications for cross-ties. That would be useless unless the instructions for inspecting the ties were also standardized, as the inspectors themselves are standardized, which is an impossibility.

Mr. F. J. Stimson(Pennsylvania :—I understood Mr. Burton to say they adopted the six-inch tie as a standard because it was of shorter life than the seven-inch tie. In looking at Table I, I understand that the table shows the same life for the six-inch white oak as the seven-inch white oak. Mr. Burton's statement that the life of the tie is controlled by the element of decay is correct, but I cannot see any reference to that in this table.

Mr. Burton :—The statistics as reported by the roads do show exactly that. It is accounted for by the fact that the larger ties in general are used on roads of heavy traffic; they are worn out, and this is reflected in Table I to a certain extent. Although the reports indicated that the ties failed to decay, actually the decay is facilitated by the wear, and inconsistency does appear at times. We came to this conclusion by asking for opinions on the point, and we also averaged the data furnished to us, these results being given in the top paragraph on page 237.

Mr. W. R. Armstrong (Oregon Short Line) :—What application will this have to western roads that do not have any oak ties, and do not use six-inch ties? I do not see any use for a standard of that kind for a large proportion of the roads of the country.

The President :—The idea is that the standard tie be used for testing, and not to adopt the standard tie for the road.

Mr. Burton :—The Committee would suggest Mr. Armstrong might purchase and try out perhaps 100 white oak ties, to determine what Salt Lake's climate is, measured in terms of these ties. Once you find this out you put your results in on a basis comparable with the results in other parts of the country, whatever may be the kind of tie commonly used. The idea is to make the reports from different roads in widely scattered parts of the country comparable.

The purpose of a specification is to secure material of like kind or of a definite kind, so that when you specify a certain grade of ties, for example, you obtain a certain definite quality. If the white oak specification does not do this, it is the fault of the specification, but the Committee, with the information it has, believes white oak is the best for the standard test tie.

Mr. C. M. Taylor (Philadelphia & Reading) :—Is it the thought of the Committee that the test track program, described in section d, on page

235, indicates the life of the ties on the average, or just the test tie section alone?

Mr. Burton:—The Committee is recommending as part of its next year's assignment, a revision of the instructions for the test sections, and I believe one of the points brought out will be that the test section should be so selected as to be representative of the road as a whole.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—On page 239, columns 1 and 3, are somewhat in confusion. For instance, I do not understand why, in the case of redwood ties, that the six-inch tie will show 1.42, whereas the seven-inch tie will show only 1.17, as compared with the white oak. It also shows that the redwood seven-inch tie compares favorably with the white oak seven-inch tie.

Mr. Burton:—That is explained, I think, by the fact that Table I is prepared from the returns without any hand picking on the part of the Committee, that is, we have not gone behind the face of the returns. We explained a moment ago that in general the larger ties are used by roads of heavy traffic, and while Table I is intended only to represent decay, we know the decay is influenced by the amount of wear and the wear by the heavy traffic.

Mr. J. L. Campbell (El Paso & Southwestern):—The ratio of durability of redwood ties given in these tables, compared with the white oak, are surprisingly low on the basis of the quality of redwood that used to be secured, but is not low on the basis of some redwood ties secured in these days. When the Southern Pacific track was laid through El Paso forty years ago, redwood ties were used exclusively. They remained in the track for twenty-five years and were finally removed on account of rail cutting. I do not recall seeing decay in any of them. In 1912 we laid about 18 miles of track with redwood ties. In ballasting that track eight years afterwards many of these ties were found failing by decay. There is a wide variation in the durability of redwood as between the butt and the top of the tree. Such variation will enter into an investigation of this kind if various kinds of redwood are used.

Mr. Burton:—The data relating to redwood is not of sufficient quantity to make it satisfactory, as there is only one road reporting the use of this material. The Southern Pacific Company, Pacific System, reported the use of seven-inch redwood ties which lasted eleven years, as against the average of eight years the country over for the white oak ties. The difference is not great, and if more roads reported we would have somewhat higher figures for the redwood, I believe.

Mr. F. J. Angier (Baltimore & Ohio):—My understanding is that you are basing the different ties on 6x8-inch white oak ties, giving a certain length of time. What kind of white oak tie is it? Northern, southern, chestnut oak, what species of oak is it? Is it a heart oak or a sap oak? What are we to use, as a white oak tie, to base the other ties upon?

Mr. Burton:—I think Mr. Angier's question is a proper one to ask, and I would call attention to the specifications for white oak ties contained in last year's report, which specify the proportion of heart and sap.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—If the Union Pacific were to buy a thousand of these test ties, and get them from New Jersey or Pennsylvania, and insert these in tracks, and use on one of their parallel tracks the same number of ties from the southern part of Virginia, they would be more than likely to get at least two or three years' difference in the life of the test ties. There is no question about it. We have had that experience with white oak ties all over the country, so that it does seem to me that the Committee must be careful about recording correct information. They must get the information at least as to where the ties came from, as there is a great difference in white oak grown in Pennsylvania or New Jersey, from the white oak grown in the southern part of the country.

Mr. Burton:—The Committee realizes that something of the kind may be a fact, but the question is, What ought we to do? We have a specification which says that a certain thing specified is what we want for white oak. Possibly the specification should be modified to call a white oak tie one thing north of the Mason and Dixon line, and something else south of it.

Mr. Angier:—Specify Virginia white oak.

Mr. Burton:—Don't you further complicate it by having a definite understanding of what Virginia white oak is?

Mr. Angier:—Many of us can remember when white oak gave us a life of ten or eleven years. The white oak today is not giving over six years' life. Thirty-three per cent are sapwood, and they are not lasting over four years. We should specify that the tie should be all heart or should be from a certain part of the country.

Mr. Burton:—The Committee would like a suggestion from Mr. Angier or anybody else as to what would be the best tie made standard. As regards sap, the specifications adopted by this Association classify heart white oak, Class U, and sap white oak is shown in Class T. The specification further details just what a heart tie is and what a sap tie is.

As regard the part of the country from which the tie is procured, that is another matter. If the same species from points in the south is greatly different from points in the north, possibly the specifications should be further modified.

Mr. John R. Leighty (Presidents' Conference Committee):—It is entirely possible that the plan the Committee has outlined will establish what seems to be a very valuable factor for equating the service life of timber of the same species from different parts of the country, if, for instance, you have some Virginia oak used by one railroad and some Ohio oak used by another railroad in the same climatic territory, and under similar traffic conditions. It seems to me you have made a step towards developing an equation factor which would enable you to measure the life of ties from one part of the country against that of ties from another part of the country, which would be a very valuable factor, when it is derived. It is entirely possible that a railroad could afford to pay considerable money to get a tie that would last more years, and this plan you have outlined, I think, will lead you to the information necessary for determining what might be done along that line.

The President:—We will now vote on the recommendations found on page 238.

(The recommendations were put to vote and unanimously adopted.)

Chairman Clark:—The Chairman of Sub-Committee No. 3 on Substitute Ties is unavoidably absent.

(Mr. Clark abstracted the Appendix B on Substitute Ties.)

Chairman Clark:—Sub-Committee No. 4 reports progress.

Subject No. 6 is "The effect of design of tie plates and track spikes on the durability of cross-ties and results of improperly protecting ties from mechanical wear." Mr. Layng will present this report.

Mr. F. R. Layng (Bessemer & Lake Erie):—The Committee has had this subject assigned to it for a number of years, and on page 259 we have recapitulated the work contained in previous reports, and we have tried on page 260 and 261 to briefly state the information the Committee now has in hand on this subject, with the idea of expressing what has been learned by this study, and with the thought that the Committee, for the present at least, can discontinue the study of the subject, having covered the subject as far as it is possible at this time.

I move that this report be received as information and the subject be discontinued.

The President:—I think the question of discontinuance of the subject is matter for the Committee on Outline of Work to consider, and the motion will be that the report be received by this convention as information.

(The motion was seconded, put to vote and carried.)

The President:—That completes the Committee's report, except for the recommendations for next year. The Committee is dismissed with the thanks of the Association.

DISCUSSION ON STRESSES IN RAILROAD TRACK

(For Report, see p. 429.)

Professor A. N. Talbot (University of Illinois):—I think you are all glad to be at the end of a very long session, and I will make my presentation on this report brief. As stated in the report, the work of the year has been given to the working up of tests already made. This has involved a great deal of detail work. I am glad to say, however, that the progress on the work has been such that we now have the material nearly in form to present to the whole Committee for discussion, and we expect to have a report during the year covering all of these tests.

The work I refer to is the calculation of the stresses in earth, both straight and curved track, in a number of types of locomotive, and the effect of both these and the counterbalance of these stresses. The lateral bending is also included.

There have also been carried on a series of tests in the laboratory on the stresses in angle bars and joints of various kinds, and it is believed that this will give information of some interest on the way the different angle bars act, and how far back it is from the end of the rail, before the rail and the bar act as a single piece, and I think that information will have an influence on the forms of angle bar which should be used.

The Committee is enabled only to present a report of progress at this time. I think, however, that all the members of the Committee will be glad to have suggestions either here or afterwards, as to the work to be done, or the work which should be undertaken.

Mr. C. H. Mottier (Illinois Central):—I would like to ask Professor Talbot if the Committee has given any attention to the distribution of pressure through embankment. I am prompted to ask this question because the Committee has done considerable work on distribution of stresses through ballast, perhaps to a depth of two feet. They have the information on that subject available, and presumably have the apparatus necessary to make further tests at a greater depth. I feel that definite knowledge as to the distribution of pressure through embankment will be of great value and I am, therefore, wondering if the Committee has in mind the development of this subject.

Chairman Talbot:—The work on that has not gone very far. Tests in the laboratory have been conducted which are applicable to the transmission of pressures through any granular material, and during the year some effort has been made to find out whether it is worth while to conduct further tests in the laboratory on the way in which the pressures are transmitted in granular material. So far as the determination of the distribution of pressures in embankments is concerned, I am afraid that tests would not result in anything of value unless done on a large scale and under many different conditions, in which case the cost of the work would be prohibitive.

I think before summer comes we shall have information that will enable us to judge if it is worth while to go into this matter further.

The President:—Are there any further discussions? If not, the Committee is excused with the thanks of the Association.

DISCUSSION ON TRACK

(For Report, see pp. 575-620.)

Mr. W. P. Wiltsee (Norfolk & Western):—The first subject, Revision of the Manual, is so connected with the second subject, that it will be preferable to have Sub-Committee No. 2 report first. Mr. Neubert, Chairman of Sub-Committee No. 2, will present the report on frogs, crossings, etc.

Mr. J. V. Neubert (New York Central):—These plans for bolted rail crossings, 701 to 706 inclusive, were included in last year's report, and we have made such slight changes and alterations as are deemed advisable and have added other plans in order to meet the various angles.

Under "Manganese Steel Insert Crossings," we recommend the adoption of plans 751 to 765. Nos. 751-2-3-4 and 7, and 762 were included in last year's report. We have made such changes and alterations as are deemed necessary, and added such other frog angles as were required to meet the general requirements. The plans referred to and offered for adoption are shown in a portfolio which was sent out as supplementary to the Bulletin.

Mr. Wiltsee:—I move the adoption of plans 701 to 710, bolted rail crossings. Some of these plans have been before the Committee for several years. They have been discussed with and criticized by the Manganese Track Society, and are the result of the joint work of the two associations.

Mr. C. W. Baldridge (Santa Fe):—I am aware the Committee put out these plans last year for discussion, but I was not able to go over the plans at that time. In the plans for crossings, so far as I have been able to look them over, I do not find any built-up crossings showing an easer rail extending beyond the joint of the rail.

Mr. Neubert:—There seemed to be some misunderstanding last year —the specification for crossing frogs was left out. Where the easer rails are necessary, we provide for them.

Mr. Baldridge:—I have had occasion to follow up some crossings with long easer rails, as compared with short easer rails, and an easer rail extending the matter of 14 or 18 inches beyond the joint will last longer than a similar crossing with a short easer rail.

The President:—Are you ready to vote whether this shall go into the Manual?

(The motion was put to vote and carried.)

Mr. Wiltsee:—I move the adoption of plans 751 to 768 inclusive—Manganese Steel insert crossings. Some of these plans have been before the Committee for several years, and are the result of the work of the Committee of Manganese Track Society and this Committee.

(Motion put to vote and carried.)

Mr. Neubert:—There seemed to be some misunderstanding. We did not print in this addendum the specifications which should have accompanied these crossing frog plans, and I will read them.

(Mr. Neubert then read the matter "Application of crossing designs and recommended practices.")

The President:—Is there any discussion of these specifications?

Mr. C. E. Lindsay (New York Central):—Do I understand these specifications have not yet been submitted to the membership?

Chairman Wiltsee:—They were not printed in the Bulletin.

Mr. Lindsay:—May I ask whether the recommendations contained therein are merely a repetition of what has heretofore been submitted to the Association?

Chairman Wiltsee:—No, sir; they are not. They are not exactly a specification, but they cover the method of construction of these crossings.

Mr. Lindsay:—Then I submit that it would be very unfortunate to have these recommendations go in the Manual without having been submitted to the Association, regrettable as the delay may be.

The President:—There is no motion before the house at the present time. I asked for discussion on the specification.

Mr. Neubert:—As I understand it, these are not specifications, but merely explanations of these plans.

Chairman Wiltsee:—If it is in order, I will move the adoption of these explanations, to be printed with the plans in the Manual.

Mr. Earl Stimson (Baltimore & Ohio):—In seconding the motion, I would like to express my confidence in the Committee, that they are not trying to put anything over. What they have to offer is not a specification, but merely an explanation, and the plans would be rather incomplete unless that was included.

Mr. W. M. Camp (Railway Review):—It seems to be overlooked that this document was mailed out to the members about a month ago. I received a copy of it about that time, I think.

Mr. Neubert:—It was not really the fault of the Committee that these were not printed. These are nothing more than instructions in regard to the application as well as drawing up the design, as we answered the question of the previous speaker. There is no catch in them, and I think if they are inserted with the plans, the plans can be used more clearly and more properly.

The President:—Does that cover your point, Mr. Lindsay?

Mr. Lindsay:—No, sir: I feel it is very improper to print something as recommended practice that has not been considered by the Association.

Mr. E. A. Frink (Seaboard Air Line):—While it would be unfortunate to adopt something by this convention that has not been put before the members, to my mind it will be still more unfortunate if this Committee has got to see the results of its work carried over for another year. I cannot pretend to remember all of that memorandum as it was read, but my recollection of it is that a large part of it is explanatory that we can adopt without question. There are, however, some paragraphs in there that lay down certain limiting angles of certain types of frogs, limiting curves, etc. I think we can solve this problem by having those paragraphs read, paragraph by paragraph and voted on, and adopting the rest of it as a whole.

Mr. Baldridge:—I did not hear anything in this explanation that I would consider objectionable. It seems to me the only objection to having this adopted without having it printed is the matter of establishing a precedent. It has been customary in the past not to allow anything to go in the Manual that has not been previously printed in the Bulletin. If that precedent is to be followed, we should let it go over another year, so that if anyone does find something there that he wants to criticize, it can be done after mature study.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I should regret very much to see this report held out of the Manual due to this delay in the presentation of a portion of it. I believe that we have time enough in the discussion of this report to have the paper that the Chairman read considered paragraph by paragraph, and I feel that it would probably receive very much more careful attention than the remainder of the report has, because I know that the volume of it is such it would prevent anyone from reading it all and studying it to the extent that would be necessary in order to criticize anything that the Committee has done.

The President:—There is a motion before the house now to adopt these explanations and place them in the Manual with the plans.

Mr. McDonald:—I move to amend that motion to the effect that we consider this section that has been read paragraph by paragraph.

Mr. H. M. Lull (Southern Pacific):—I do not recall that there is anything on these plans specifying the kind of bolts to be used in these crossings. I did not hear anything in the explanation relating to that.

Chairman Wiltsee:—Under the General Specification you will find that we specify heat-treated bolts.

(The motion to include the matter under consideration in the Manual was put and carried.)

Chairman Wiltsee:—I will now present the matter appearing on p. 577: "Supplement to specifications for switches, frogs, crossings and guard-rails." This is supplemental to the specifications adopted last year. We feel that this supplement, which is a specification for making Manganese steel castings, will be of special assistance to inspectors on work of this kind. I move that it be approved and printed in the Manual.

(Motion put and carried.)

The next subject appears on page 581—"Submit final plans and specifications for track tools, collaborating with Committee on Ballast." Mr. T. T. Irving, Chief Engineer of the Grand Trunk, is Chairman of that sub-committee, and he will present the report to you.

(Mr. Irving then presented the matter in question and said:) There is one dimension missing in the pickeye adze. In the elevation drawing the bottom dimension should be marked 3 in.

Chairman Wiltsee:—I move the adoption for printing in the Manual of the following plans: Pinch bar, lining bar, two claw bars, track wrenches, adze, pickeye adze, spike pullers, rail fork, track gage, rail tongs, track chisel, clay pick, spike mauls, sledge, and two track levels.

Mr. Lindsay:—On pages 582-583, lining bars and switch bars are shown. The limit of wear is indicated in outline by a measurement from the initial point of the bar. In the event that the point is worn off, you will not have any place to measure from. Also, I think it is as necessary to show the owner's name on the bar as the manufacturer's name. I would like to have the Committee include in the plans instructions that the owner's name appear on it. Why is it necessary to have bars of 18 lb. weight and bars of 20 lb. weight? Why not have two classes—18 lb. and 26 lb.?

Mr. P. C. Newbegin (Bangor & Aroostook):—In the design for claw bars, there does not seem to be any necessity for making such a heavy bar. In design No. 1 a typical bar is shown, 1 inch, and in design No. 2, a bar 1⅜ in. It would seem to me that the size of the handle could be cut down to advantage to save carrying unnecessary weight.

Mr. Camp:—For a lining bar the Committee shows a crow-bar, or one with a wedge point. It seems to me that a pinch-point is preferable for a lining bar. For all other purposes there is no question about it. If one tries to lift up the end of a tie with a crow-bar, the bar will slip back. Either a wedge point or diamond point is a poor one for a lining bar.

Mr. Neubert:—The name for that tool is lining bar, and is what is being manufactured and used on railroads in this country. The Committee felt it should be given that name and called a lining bar.

Mr. E. D. Swift (Belt Railway of Chicago):—On page 592 a track chisel is shown. The minimum size of the chisel is of no consequence for cutting the rail.

Mr. Baldridge:—It struck me in looking over these plans that the size of the jaws of the rail tongs as shown on page 591 were unnecessarily close to the size of the present rail head. Rail tongs ordinarily last for a good while and it seemed to me it would be better to allow a little larger spread and depth, particularly the depth of the jaws of the rail tong. Rail tongs do not wear out very fast and should be made to take care of a variation greater than is shown.

Mr. Neubert:—The rail tong shown here will take care of a Pennsylvania 130-lb. rail section.

Chairman Wiltsee:—The Committee went into that question very carefully.

Mr. Baldridge:—I believe that 2¼ in. depth, which is the amount allowed here, is hardly enough clearance to protect against what may occur in the design of rail heads in the future, and there is no reason for holding to a close fit between the depth of the grip of the tongs and the rail head that I know of. It is a case of providing an extra half-inch in a vertical direction, to take care of deeper rail heads which may be in use in the future, and would not in any manner interfere or cause any trouble in handling a rail of smaller size.

Mr. Camp:—I agree with Mr. Baldridge. It is more important to have some leeway in the vertical depth than the lateral depth. Even if the jaws do not come together on the web, it would not make so much difference, but if there is not vertical depth, it might be impossible to grip the head of the rail at all with the tongs. An extra half-inch would not do any harm and might accommodate the use of the tongs to heavier rail than these tongs shown here.

Mr. L. J. F. Hughes (Chicago, Rock Island & Pacific):—As to track gage on page 590, I should like to inquire of the Committee, if, in determining upon this design of a track gage, they considered the type of gage in which there is a curved recess on the face that bears against the rail to allow for a possible bead on the rail. If it has considered that type of gage, I would like to know the reasons for not embodying this feature in the track gage which they set forth as standard.

Mr. Earl Stimson:—The double-ended track wrench is in quite general use, and I would like to have some expression from the Committee as to why they limit the design to the single-ended wrench.

Chairman Wiltsee:—The question of track gage with a beaded edge to take care of the lip on the rail was before the Committee, and discussed considerably. On account of the wear, and not being able to get a very strong gage, especially at that point, the Committee thought that this type of gage, which provides for gaging the track at the gage point ⅝-in. below the top, was a strong gage and better in all respects.

In regard to the double-ended track wrench, the Committee did consider that question, but decided that the single-end wrench was preferable, although there was no objection to using the double-ended wrench if anyone desired. I think that ordinarily for rail-laying gangs the single-ended wrench is preferable, particularly with the drift end, but possibly on a section the double-ended wrench may be preferable.

Mr. Lindsay:—What was done with the shovel recommended by the Ballast Committee yesterday, the plans of which do not agree with this plan? I wonder if the conflict can be reconciled?

Chairman Wiltsee:—I did not include the track shovel in my motion to adopt this plan.

Mr. Baldridge:—I am inclined to agree with the gentleman who spoke in regard to the track gage. The form of track gage as shown is all right to use on new rail, but practically all rail of present day usage acquires a bead, or an overhang projection, on the gage side of the rail after comparatively short service, which makes it impossible to gage a track ⅝-in. below the top of the rail, as provided for theoretically, with this gage. On the Santa Fe we use a gage which provides a recess under the upper corner of the gage above the gage point to take care of this irregularity in the head of the rail, and I think that such a gage is preferable to the one shown.

What I want to get at is this idea, to ask the Committee to bring in an alternate plan gage in another year's work, if that can be arranged.

Mr. Camp:—This question of gaging the rail at a point on the side of the head came up in this convention several years ago, and there was a lengthy discussion about it, and that point ⅝-in. below top of head was adopted as a sort of a compromise. I presume the Committee had in mind it ought to stand. I think we had better be a little careful about changing it now. It was the result of a lot of work on the part of the Committee, and from discussion on the floor.

The President:—The motion is that we adopt the plans as shown and read a few minutes ago.

(Motion carried by a rising vote.)

Chairman Wiltsee:—The Committee submits the plan of the track shovel on page 598 as information.

The President:—It will be so received.

Mr. Frink:—I move that the design of track shovel as prepared by this Committee and presented as information be sent to the American Engineering Standards Committee for their handling, along with the design presented yesterday by the Committee on Ballast.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I do not believe that is a wise move. My thought would be that this Association, when it sends to the American Engineering Standards Committee a design, ought to be unanimous about it. The Ballast Committee has submitted a design for a shovel, which was voted to be sent to the Standardization Committee the other day, if I remember correctly. Why cannot the Track Committee subordinate its ideas to the Committee on Ballast, and give one design of shovel that will be satisfactory to this Association? If this shovel it satisfactory to send up to the Standards Committee, why should we send a conflicting one?

Chairman Wiltsee:—I do not think there will be any doubt but what the two committees can get together on that subject.

Mr. H. L. Ripley (New York, New Haven & Hartford):—I thought that matter was settled yesterday afternoon by Mr. Stimson's substitute motion to the effect that matters should not go to the Standards Committee until they have been adopted by this Association. Such a vote as Mr. Ray suggested was taken in the morning, but I thought the action taken in the afternoon killed it. Neither the Ballast Committee's shovel nor this shovel has been approved by this Association, and if I recall the vote taken when the Standardization Committee was on the platform, it cannot and will not go to the Engineering Standards Committee until one shovel or another has received the approval of this Association.

The President:—You are correct, Mr. Ripley. The second motion nullifies the first, and I will declare this one out of order. Proceed with the Committee's report.

Chairman Wiltsee:—The next subject is shown in Appendix D. Specification and unit track work schedules for contracting maintenance work—will be presented by Mr. E. T. Howson, Chairman of the Sub-Committee.

Mr. E. T. Howson (Railway Age) :—While many roads have adopted the cost-plus form of contract during the last two or three years, your Committee felt that this is little more than the recognition of the contractor as a labor agent, and for that reason it did not consider that form of contract as coming within the scope of the instructions to it. It has, therefore, confined its attention to that work which may be contracted on a unit-price basis. The Committee has also received suggestions from some railway men and others that all maintenance work may be contracted under a blanket contract, but the Committee has confined its attention to three of those items which can be measured, and for which specific contracts can be made. The Committee therefore presents specifications and unit schedules for the relaying of rail; the stripping of track and the renewal and respacing of ties, and for ballasting.

I would like to call attention to two or three errors in the report as printed: In the next to the last line in the last paragraph of the introductory statement on page 599—"removal of ties" should be "renewal" of ties.

In the specifications for relaying rail, near the bottom of page 602, in the last line of the lower tabular matter, "efficiency equals 400 *plus* 405" should read *"divided by* 405."

On page 604, 2 lines from the end of the first long paragraph near the middle of the page, 15 inches should read "18 inches."

On page 606, in the tabular matter under "example," fourth line, should read "total standing hours *equals* 1676," etc.

The last line of that example should read, "Efficiency equals 732.97 *divided by* 810," etc.

The Committee presents specifications for the relaying of rail by contract, beginning at the bottom of page 599 and continuing to near the bottom of page 602. It presents similar specifications for the ballasting of track by contract, beginning near the bottom of page 602 and continuing almost to the bottom of page 606. The Committee presents specifications for the stripping of track, the renewal of ties and the respacing of ties, beginning near the bottom of page 606 and continuing to page 610.

Chairman Wiltsee :—I move the adoption of the specifications just referred to, as shown on pages 599 to 610, inclusive, and that they be printed in the Manual.

Mr. Earl Stimson :—Will the Committee please state whether the unit track work schedules are to be made part of the specifications, and if not, just what they are supposed to be?

Mr. Howson :—Those unit track work schedules were submitted in accordance with our interpretation of the instructions of the Board of Direction in the assignment of topics, and also as an example of the operations included within this specification, the two being made consistent.

Mr. Baldridge:—In the specifications for relaying rail on page 201, article 19, reads: "As far as possible all joints should be kept out of streets and road crossings, using long or short rails for this purpose."

Following that we come to article 20, reading: "Rails must be spiked in full to each tie," etc. I am going to offer this suggestion, that a clause be inserted between articles 19 and 20, reading: "New rail shall be so laid that insulated joints will be brought near enough to the old location of the insulated joints so that it will not be necessary to move trunking, wiring, etc."

Chairman Wiltsee:—The Committee will accept that amendment.

The President:—That being the case, the motion for the amendment is out of order. Proceed to the discussion of the original order.

Mr. W. C. Barrett (Lehigh Valley):—I would like to ask the Committee if they have considered in this specification for laying rail, the use of machines by contractors. Apparently the specification calls only for the laying of rail by hand.

Mr. Howson:—There are so many widely-varying practices with reference to each particular operation which we have endeavored to cover by specifications, that the Committee became aware very early in its work that it must confine its specifications to those details of work on which there was fairly general agreement. It therefore left out of this specification many details which an individual road would incorporate, but it did endeavor to cover the basic principles which would serve any individual road. Therefore, we did not incorporate in these specifications reference to the use of mechanical equipment, because that equipment itself varies in detail, and the specification would have to be so drawn as to imply the use of certain types of equipment, which might or might not enter into the operation, on a particular road.

Chairman Wiltsee:—I think if the members will attempt to apply these specifications to their own conditions, they will find some few changes or revisions necessary, which are naturally to be expected. I just had occasion to do this on our own road, and found that I had only a few changes to make to suit our conditions. Generally they fit.

Mr. Lindsay:—I do not care to prolong the discussion, but I would like to make one fundamental objection: I would dislike very much to see this convention degenerate into a rubber-stamp. The Committee gave no indication in its recommendation that this subject was to be included in the Manual. I think we should jealously safeguard the Manual, and while these specifications are valuable, they will be just as valuable for the next year to the Association members in the Proceedings as they would be in the Manual. The whole subject of contract work is boiling. Nobody knows where they are. These specifications will be of value in guiding those who are undertaking other processes, but I submit that there has not been sufficient time to study this subject in its entirety and to go into it as it should be done before it is inserted in the Manual.

The President:—If that is your thought, Mr. Lindsay, why not make an amendment to put it before the house, and let them decide?

Mr. Lindsay:—I move to amend the motion, that this subject be accepted as information and placed in the Proceedings.

Mr. Earl Stimson:—I concur fully in Mr. Lindsay's amendment, and I think it would be quite dangerous to adopt this matter offhand. Referring back to the question I asked the Committee—it was not answered fully, as to just what use or what purpose the unit track work schedules serve in the specification. They are no doubt very valuable information, but I cannot see what place they have in a specification that you are sending out to the contractor.

(Mr. Lindsay's motion was adopted; also the original motion as amended.)

Chairman Wiltsee:—The next subject is plans and specifications for switch stands, switch lamps and switch locks, shown on page 611. Mr. Macomb, Chairman of the Sub-Committee, will present the report.

Mr. J. deN. Macomb (Santa Fe):—The first item assigned to this Sub-Committee is a revision of the Manual, which will be taken up by the Chairman of the General Committee.

(Reading second and fourth paragraphs, page 611; also the fifth paragraph.)

Then follows a reference to six signal section plans, the intention being to read them into our Manual, but not to re-publish the drawings or material in our Manual, as it is a duplication of Signal Section material, and incidentally in that connection the Committee feels that this is the border line between the Signal Section's jurisdiction and A. R. E. A. jurisdiction, and that recognizing the Signal Section's standards is as far as we could go.

(Reading last two paragraphs, page 612.)

Chairman Wiltsee:—I move the adoption and printing in the Manual of Plan No. 254 of 10 and 9 in. target discs.

(Motion duly seconded and carried.)

I move the adoption for printing in the Manual of our approval of the Signal Section Plans Nos. 1440-41-42-43-1460-61, these to be approved and endorsed without publication of the plans.

(Motion duly seconded and carried.)

Chairman Wiltsee:—Next with this Sub-Committee's work we have one item on Revision of Manual, shown on page 577, item 2.

(Reading item 2 on pages 577-78.)

I move the adoption for printing in the Manual of Plan No. 252, and also the revision of Section 12 as proposed.

(Motion duly seconded and carried.)

Chairman Wiltsee:—We will now take up Appendix F, "Gages and flangeways for curved crossings." Mr. Angerer will present the report.

Mr. V. Angerer (William Wharton Jr. & Co.):—The task assigned the Sub-Committee was to reduce the concrete practical rules and to compare with results in actual practice the study on gages and flangeways submitted as information at last year's convention. This has been done, and the Committee submits tables No. 1 and 2, printed in the Bulletin. Table No. 1 is a practical table for reading off the gage required on various degrees of curvature for locomotives with rigid wheel bases given on the left-hand end of the table. Series "A" of the gages corresponds to the present rules of the 1915 Manual, and the wheel bases given for this series of gages shows that they will serve average main line conditions, thus confirming the present rule. Special conditions and unusual conditions are covered by the other figures. Particular attention is called to the notes on the table which should be studied, and in connection with note 3, it should be borne in mind that the table deals with a rigid wheel base of the locomótive and the swing of the trucks must be sufficient for the degree of curvature in order to enable the locomotive to operate on the gage and width of flangeway of the table. The figures in such a practical table necessarily must be approximate within certain fractions. To get more exact figures, if desired, the diagram, table No. 2, is submitted in which any additional lines for other wheel bases than those given can be interpolated.

Chairman Wiltsee:—I move that tables Nos. 1 and 2 be adopted and printed in the Manual.

The President:—This is a splendid report of the Sub-Committee, and well worthy of your consideration. Is there any discussion?

Mr. J. B. Jenkins (Baltimore & Ohio):—These two tables, in my estimation, are two of the most valuable tables that have ever been presented to this Association. Apparently hundreds or thousands of calculations have been condensed into a single table, showing the relation between wheels, degree of curve and gage, and are worthy of the careful study of every maintenance engineer; it should be put in the hands of every designer of locomotives and the effect of the locomotives that are running on each particular road should be carefully studied in the light of these tables.

(Motion put to vote and carried.)

Chairman Wiltsee:—In connection with this matter, there is revision of the Manual necessary. These items are shown under "Item III," on page 578. I move that these be adopted and printed in the Manual.

(Motion put to vote and carried.)

On the next subject, "(a) Tests of tie plates subject to brine drippings; (b) effect of brine drippings on track appliances," we expect to conduct further inquiries and the Committee will report at a later time.

The next subject is: "Investigation on reduction of taper of tread to 1 in 38 and on canting the rail in track inward." The Sub-Committee in charge of this subject have reviewed the matter that has been reported in the past, and tried to collect new information, but they have not been able to get much of value, and the report is submitted as information.

That concludes the report of the Committee.

The President:—The Committee is excused with the thanks of the Association.

DISCUSSION ON SHOPS AND LOCOMOTIVE TERMINALS

(For Report, see pp. 263-391.)

Mr. F. E. Morrow (Chicago & Western Indiana):—The report of your Committee on Shops and Locomotive Terminals is shown in Bulletin 241. I will ask Mr. G. H. Gilbert, Chairman of the Sub-Committee on Ash Pits, to present that portion of the report.

Mr. G. H. Gilbert (Southern):—The subject of ash pits was one of the first subjects assigned to this Committee when the Committee was formed two years ago. Cognizance was taken of the fact that this Association has been criticized in the past because we had not presented suitable information in regard to ash pits. The technical press has criticized us for not giving definite recommendations.

The same subject had been previously considered by the Buildings Committee. Fortunately, several of the members of that Committee were retained on the Shops and Locomotive Terminals Committee, so that we were fully informed as to the past handling of the matter. The reason no more definite action had been taken in the past was because of the large conflict of opinion and because the underlying conditions surrounding the operation of ash pits are so varying in their demands.

Your Committee hoped by being a little exhaustive to finally determine all the essential facts, or in any event enough facts to justify us in recommending a few special designs and making concrete definite recommendations. We admit we have been unable to do so, and have only been able to present to you as much information as we think any committee can accumulate on this subject at the present time.

With that background we are offering for your action at this convention a summarized report for inclusion in the Manual. We think the subject and the subject-matter is of such importance that a condensed report is worthy of a place in the Manual. With that explanation I will ask you to turn to the report. I would like to call your attention to a few matters that are not given in the summary.

On page 269, please refer to the middle paragraph. This is a description of a type of pit which was not shown in last year's report, a type being used by only one road. The Committee at this time does not want to give any very definite recommendations on this type, but it seems to have some very favorable aspects—it is a deep water pit of a circular type.

On page 273 is a reference to the laws of both Canada and the United States regarding ash pans and labor under locomotives.

On page 274 is given detail information in regard to the actual construction and location of ash pans. There are many ash pits where the ashes are discharged into pits or hoppers, and it is, of course, vitally necessary to know over what area the ashes are discharged, and how they are discharged, whether they fall vertically, are blown out, and to what extent they pile up, whether the ashes fall between the rails or outside of the rails.

This information is based on possibly 40 representative ash pan drawings received from locomotive manufacturers, and a few leading railway systems.

In this connection, please refer to the diagrams on page 322 as an aid in explaining the detail figures and discussion previously given. Your attention is directed to several of them, Nos. 3, 6, 7 and 9, which have what the Committee calls "outside ash pans." That means an ash pan that is located outside the rails, and either discharges outside the rails or upon the rail.

When we first received these plans we were somewhat puzzled, because so many ash pits are designed wholly to receive ashes between the rails, and because we were very well aware that with heavy modern power it has apparently been hard to design ash pans which would have required capacity and be so located with due regard to clearances from locomotive parts that the ash pans could discharge between the rails in the ordinary pit. We have found, however, by correspondence with the different manufacturers and railroad systems, that in all probability the use of these outside plans will be very restricted in the future. We believe we are justified in recommending to the Association that such pans be not included in ash pit design unless on a road where they are actually in use, or their use is contemplated.

On page 275 is given a certain amount of information regarding the time that it takes to clean the locomotive fire on the ash pit. The fundamental question, of course, in the design and layout of ash pits is to pass the engine over the pit without delay in the least possible time, at as low a cost as possible. We endeavored to determine the time it takes to clean fires. Your Committee hoped to get a great deal of data from time studies. The data presented here represents possibly 10 or 12 terminals, as an actual time study of one day each at the terminals. You will notice that the data is not in any wise conclusive, but unfortunately we could not get enough such checks to present data that is of general value. We simply call attention to it, because on any local road the same procedure must be done, if you are going to gage the amount of time an engine will be on the ash pit.

On pages 276-77 is given considerable information on what is called the operating payroll cost per engine. This data is for use in connection with the tabular information beginning on page 290 and running to page 321. You will notice that this data embraces an actual 28-day test of the cost at 95 representative terminals throughout this country, including all the common forms of ash pits. It shows actual cost, actual number of fires cleaned, and data in regard to the force, when they work, and the rates of pay. It would seem that such comprehensive and accurate data would give us some information by which to finally judge the relative value of each common type of pit, but careful analysis and consideration will show that this data is valueless for comparative purposes. It is of value by showing that if you go through the same procedure you may get the same results. It is not of any value for the purpose of formulating conclusions.

Please note on page 277 we have attempted to give an average cost per engine for the different types of pits. The variation is from 80 cents to $1.17, or an average of 97 cents. You can, of course, find cases where pits are cleaned at a lower cost than this.

On page 278 we give a "Summary." The Committee offers this matter as covering in a comprehensive way all the considerations which should govern the layout and design of ash pits, including the general matter of ash disposal.

The Committee expects to move that this matter be included in the Manual, and if it is the wish of the convention I would suggest we take the subject-matter up in detail.

The President:—I suggest you read the headings, and we will pass on it according to the headings. Is it the intention of the Committee that this should be placed in the Manual?

Mr. Gilbert:—Yes, sir, and I move that the matter appearing under the head of "Summary" be accepted and included in the Manual.

Chairman Morrow:—I do not know whether that motion is just what the Committee would like to have or not. The Committee has recommended that all of the matter beginning with the "Summary," to the end of the matter on page 289, be included. If you wish to pass on it separately, it is entirely agreeable to the Committee.

Mr. R. G. Kenly (Minneapolis & St. Louis):—My understanding is that things going into the Manual go into the Manual after they are approved as recommended practice. This summary is simply a summary of conditions found to exist in various parts of the States. I do not find any recommended practice, in this type of summary.

Mr. Gilbert:—Perhaps I did not make myself clear. We have been at work on this for two years and we feel that after doing more work than has been done by any other committee that we are still not in position to present definite conclusions. The practical situation is this—either this governing and essential information must be accepted or the Association will have no material in the Manual which is worthy of it. We have offered this for insertion in the Manual as containing essential information on the subject. We do not feel there is a single matter mentioned in this summary which should be omitted.

Mr. J. L. Campbell (El Paso & Southwestern):—Is the Committee submitting this as information or as a statement of principles?

Mr. Gilbert:—Both.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—Without attempting to discredit the valuable work of the Committee, I believe that what they have submitted here is information and not recommended practice. I think the Manual would be better off without anything on the subject than to have something as general as this put in.

I move to amend the motion before the house by printing this as information in the Proceedings, and not in the Manual.

(The amendment was put to vote and carried.)

Chairman Morrow:—The next subject which the Committee has to report is "Engine Houses" under the assignment "Engine house and power plants and shop extension, collaborating with Division V—Mechanical." In the absence of Mr. G. W. Burpee, Chairman of the Sub-Committee, I will ask Mr. L. P. Kimball to present the report.

Mr. L. P. Kimball (Baltimore & Ohio):—On page 326 the Committee has attempted to lay down certain recommendations regarding engine house design as the result of the information secured from questionnaire. We also show certain plans in connection with our recommendations as a matter of information.

As a result of this study, there is a recommendation for the replacement of the existing matter in the Manual, with the matter shown on pages 337-340 of our report.

I move that this matter be accepted by the Association and substituted for the present engine-house material in the Manual.

(The motion was put to vote and carried.)

Chairman Morrow:—On page 351 is shown the next subject, "Engine Terminal Layouts," under the assignment, "Engine house and power plants and shop extension, collaborating with Division V—Mechanical." This work was initiated in connection with our collaboration with the Mechanical Division committee. This is presented simply as information.

This is followed by Appendix D, "Design of Car Shops," report on passenger car repair shops. This is also presented as information.

The President:—As information the convention will receive it. This ends the work of this Committee. They have rendered us a valuable service, and they are dismissed with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY LOCATION

(For Report, see pp. 427, 428.)

Mr. A. S. Going (Grand Trunk):—Your Committee on Economics of Railway Location presents only a report of progress. The report of the Committee will be found on pages 427 and 428 of Bulletin 241.

The report is offered as information and I move that it be so received.

The President:—The report will be received as information, and the Committee relieved with the thanks of the Association.

DISCUSSION ON ROADWAY

(For Report, see pp. 393-425.)

Mr. J. R. W. Ambrose (Toronto Terminals Railway) :—The Committee were assigned eleven subjects, and as requested by the Board of Direction, we have tried to make our report just as concise as possible. The action recommended is shown on the first page, 393, the details of which are shown on the following pages. The first subject is Revision of the Manual, shown on page 394, under Appendix A. Your Committee during its work was very much surprised to find that the term "casting" was not generally used and was not understood between different sections of the country. Therefore we have prepared a definition for casting, as well as for "station men" and "station work," those terms being used throughout the report. I move that these be approved and placed in the Manual.

(Motion duly seconded and carried.)

There possibly will be one or two other definitions that will be embodied in the sub-committees' reports.

The second subject, "Shrinkage and Swell of Grading Material," Appendix B, page 395, will be presented by the Chairman, Mr. McVay.

Mr. C. M. McVay (Kanawha & Michigan) :—The subject of shrinkage and swell of grading material has been considered in this Committee now for I believe about five years. Originally we had an assignment which included subsidence with this subject. The Committee has already reported quite extensively on that subect. The subject was re-assigned and we went into it to some extent this year, as much as we could, but we find it very difficult to get information that will give us what we want. It is almost impossible to go any further with the subject than we have gone so far unless we get some additional information. We have presented a form, which you will find here in this report, and we would like to have the information, if possible, kept by some of the railroads according to this form, so that it can be available for the consideration of this subject by the Committee in the future. We want to call especial attention to item No. 6 in that form, which has been the principal stumbling block for this Committee: "If any additional filling material was put on the embankment during the settling period, so state, showing material and yardage."

We found in the investigation explained in this report, when an embankment was widened out with industrial waste, slag, cinders, and stuff of that kind, we could not find how much of that material had been put on, so that it is almost impossible to get the comparison between excavation and embankment that was needed in the consideration of the subject of shrinkage.

It is the understanding of the Committee that this report which is made this year will be simply received as information.

The President:—Unless there is objection it will be received as information.

Mr. Edwin F. Wendt (Consulting Engineer):—Before that subject is passed, I note that the Committee has expressed a desire that further consideration of this subject be discontinued, at least temporarily. I trust that the Committee will not press that request, and that the Board of Direction and the Committee on Outline of Work will continue this subject, particularly because there are some new lines under construction at the present time—in fact, there are more new lines under construction today than at any time within the past five years, and information on this subject should be secured from the time of original construction. The subject is one of much more importance than is generally understood. The Committee states that there is no reliable information on this subject. It seems to me that is a very good reason why the Committee should constantly be looking for additional reliable data. So that I trust the Committee will recommend to the Board that the subject be continued, and that the information be reported from year to year as it develops.

Mr. McVay:—I might say to Mr. Wendt that the Committee did not make this recommendation with a desire to get rid of the subject, or anything of that kind, but simply felt that it might be well to wait just a year or two until some of the information that we were after could be made available. The Committee realizes that it is a subject of great importance, and our principal trouble has been to convince the other fellow that it is important enough to give us this information so we could work it up right.

The President:—Your suggestion will be given consideration by the Committee on Outline of Work.

Chairman Ambrose:—The third subject, Appendix C, "Methods Employed and Results Secured in the Treatment of Sliding Cuts and Fills and Soft Spots in Excavations and Embankments," will be presented by Mr. Daley, Chairman of the Sub-Committee.

Mr. C. A. Daley (Erie):—Upon investigation of this assignment it was found that the report of the Roadway Committee, under the chairmanship of Mr. George H. Bremner, contained in Volume 10, part 2, 1909, covered the subject very well, and from the information that the Committee has received from various railroads, we were unable to enlarge upon this report to any great extent. We did receive, however, a few interesting experiments in the intercepting of sub-surface drainage, which are shown on page 400, a report by the Kanawha & Michigan, the Virginian Railway and another from the Southern Pacific; also one from the Northern Pacific, as shown on page 401.

In our investigation we found that soft spots were not defined in the Manual, and we have included under conclusions a definition. We also found it advisable to rearrange the conclusions in the Manual and submit the following conclusions to be published in the Manual, shown on page 403, under the head of "conclusions."

Chairman Ambrose:—I move these conclusions be adopted and placed in the Manual as read.

Mr. J. L. Pickles (Duluth, Winnipeg & Pacific):—On page 399 of this report I notice they say: "Where the soil is poor it is desirable to enrich it with street sweepings or manure." You will find that street sweepings are not what they used to be. They are about the best thing in the world to put on a slope now to keep down vegetation.

(Chairman Ambrose's motion was carried.)

Chairman Ambrose:—The next item, No. 4, is a progress report. The Committee, under Mr. Gowdy, has spent a good deal of time during the past year in analyzing the subject. It is rather complicated and the Committee will be able to report next year.

The fifth subject, relating to the filling of bridge openings, will be presented by Mr. J. C. Wrenshall.

Mr. J. C. Wrenshall (Philadelphia & Reading):—It is the thought of your Sub-Committee that this work should be continued during the next year, and that this report dealing with the physical character of the work can be continued with advantage, and amplified by a consideration of the economics of filling, and I would like to see the Committee continued along those lines, and in the meantime I move that the report be received as information and published in the Proceedings of the Association.

Chairman Ambrose:—Mr. Wrenshall's Committee has in reality prepared a specification. We were not asked by the Outline of Work Committee to do this, but I think that the information in this report will form the basis for a perfectly good specification for bridge filling, and throughout our consideration of the subject we found that the study of the economics of bridge filling would be a very pertinent point and in our outline of work for the next year this is included.

Subjects 6 and 10 are combined in one report, shown in Appendix F, on page 413. Unfortunately Mr. Tyrrell, the Chairman of the Sub-Committee, is not present, and I shall ask Mr. Frank Ringer, one of the members of the Sub-Committee, to present the report.

Mr. Frank Ringer (Missouri, Kansas & Texas):—The Committee considered that these two subjects, namely, "The relative economy and advantages of various methods of ditching earth cuts, cleaning and shaping roadway ditches, roadbed and ballast shoulders, with special reference to labor-saving devices now in use, and the development of machinery for this purpose," and "Methods of providing outside ditches for main track drainage without utilizing the main track for loading the excavated material," could be combined under the general term "Ditching." The cost figures on page 413 are approximate only, and derived from data furnished by 30 per cent of the railroads for the use of the Committee. They are significant, but the Committee could not reach definite conclusions, as the cost necessarily varies on account of the conditions under which the work is done and the methods.

The methods in general use are outlined on page 414.

(Mr. Ringer then read the conclusions on page 415.)

Chairman Ambrose:—I move that these conclusions be approved and placed in the Manual.

Mr. R. H. Ford (Chicago, Rock Island & Pacific):—Would the Committee be willing to change the paragraph reading, "The ditching of cuts is of great importance and should be carried out currently with the regular yearly maintenance program," so as to read, "The ditching of cuts is of great importance and should be carried out currently *as part* of the regular yearly maintenance program"?

Chairman Ambrose:—The Committee accepts that.

Mr. C. A. Morse (Chicago, Rock Island & Pacific):—I would like to hear some discussion with reference to paragraph 5 as to the use of spreader cars equipped with wings for shaping ballast shoulders, roadbed shoulders, ditches and slopes. I would like to hear from Mr. Ford on that item.

Mr. Ford:—As paragraph 5 is written, nothing could be further from the truth. Mechanical ditching as a part of the regular maintenance program, either for heavy or light traffic lines, has become an important item in any well considered program where true economy in maintenance has been developed. There is no reason why a mechanical ditcher cannot be used on any line. I do not know the source of information from which the Committee developed its costs for such work, but those shown in the table are greatly in excess of actual ruling costs for practical every-day performance where the work is reasonably well organized.

There is now no justification for spending maintenance money for general hand ditching, because it can now be done mechanically, irrespective of traffic on the line. On some divisions the Rock Island is doing its right-of-way ditching by ditching machines at the rate of from 10 to 25 miles a day.

Chairman Ambrose:—The Committee agree with you on that, but I think perhaps Mr. Morse was a little bit misled. If you will notice, you are quoting from the section under shallow cuts.

Mr. Ford:—Irrespective of the depth of the cut, ditching can be more cheaply, and just as effectively, done by mechanical means. If the gentlemen who have preceded me will take the time to go into the matter thoroughly, I am satisfied that they will agree there is no reason why we should be spending the vast sums we are spending for hand ditching. This is what I meant to convey.

Mr. Ringer:—I do not think the Sub-Committee could agree with Mr. Ford that the density of traffic is not a factor of the cost of ditching. I think it is just the reverse. The conclusions of paragraph 5 set forth the usefulness and economy of the spreader car and ditching equipment on lines of moderate traffic. It was the opinion of the Committee that on lines of dense traffic, with frequent fast trains the expense and delays incident to work trains under such conditions should be avoided as a rule. Of course, the question would arise—what is dense traffic? There is a variation of opinion, and other conditions enter which would affect it, such as double-track. It is the question of the cost of work train service under such traffic conditions that is involved.

Mr. Ford:—While I have no serious objection to the first definition and its conclusion, I trust that the convention will require the Committee to give this subject further consideration. It would be unfortunate for this Association to go on record as approving any such policy as conveyed in the language of the report, and I desire to repeat what I have previously said in effect, viz.: That the Committee is fundamentally wrong if they advocate hand or manual ditching for railway maintenance, because it is expensive and unnecessary and a positive waste of money. This has passed the opinion stage; it is a well-developed fact. Ditching by mechanical means offers one of the big opportunities for saving in railway maintenance. Apart from trimming up, etc., the time has gone by when we can afford to do ditching by hand, and I trust the Committee will not insist on putting into the Manual a recommendation that manual labor be used for this purpose in any general maintenance program.

Mr. J. A. Stocker (Toledo & Ohio Central):—I agree with Mr. Ford. We attempt to do our ditching by mechanical means. We have two mechanical outfits and are trying to get a third on 800 miles of railroad. I think it is a mistake in this report not to put more emphasis on mechanical ditching and less on hand ditching. I think the hand ditching days are gone by. We use mechanical ditchers for depths less than six feet. I think we use them for ditching six inches deep.

Chairman Ambrose:—The Committee's idea is based on economy. and we are for mechanical ditching just so long as it spells economy. If we find we can ditch by hand for less money than otherwise, we prefer it, and I think we have worded our report so as to cover this subject both ways. The idea is if it can be done more cheaply by hand, it should be done that way.

Mr. J. V. Hanna (Kansas City Terminal):—I would like to ask whether the Committee has any actual cost figures to support their view that there are times when hand work is economical.

Mr. Ringer:—One answer to that is the fact that it is being done.

Mr. Hanna:—I want to ask Mr. Ford if he has included teams in hand work?

Mr. Ford:—No; I excluded team work. In this connection it will be of interest to know that on one division of a certain large Western railway, in one year $120,000 was spent for team and hand ditching. The following year mechanical methods were substituted and more work was done and the expenditure was only about $12,000, and this is not an extreme case either.

Mr. J. B. Jenkins (Baltimore & Ohio):—I would like to ask Mr. Ford if he would use a mechanical ditcher on a line of railway if he could not use the main track more than 15 minutes out of eight hours?

Mr. Ford:—I did not think that Mr. Jenkins meant to be taken seriously. I had occasion some time ago to check the density of the traffic on the heavy division of his line with traffic density on the Illinois Division of our line where we were using these mechanical ditching machines. Now, I do not like to have him press me for an answer to this question because it involves operation and I do not want to criticise the Operating people of any railroad.

Mr. J. V. Neubert (New York Central):—I would like to ask Mr. Ford another question, and that is how he is going to handle it in rock cuts?

Mr. Ford:—I do not know how any hand ditching is going to be done in the way of digging soft material out of rock. I assume that if he has a rock cut, the first thing to do is to get enough rock out of there so that some means can be taken mechanically to take the soft stuff out.

This is no guess work. I am not theorizing about it. It is a very practical business matter, and I know there are a great many men in the room here who know that this represents one of the big opportunities for saving in maintenance of way work on our American railways.

Mr. Morse:—I did not intend to start anything, but it reminds me of a good many years ago at one of the conventions when we had a very lively discusssion about slag ballast. After we had discussed it up one side and down the other, we found that one party was talking about precious mineral slag and the other about steel and iron slag, and they were two entirely different things. I remember taking a ride one time with Mr. Atterbury, of the Pennsylvania, in which he told me about some line they had on which they despatched a train every 15 minutes, but we are talking about the general trend of railroads. We have been following up this ditching proposition and the development of the spreader ditchers and we have shown some wonderful results. To illustrate, a year ago last winter I was down on one of our Southern divisions and we had just gotten our first spreader ditcher. It was between Christmas and New Year's, and the Roadmaster got on at the division point and said: "I want to ride with you a little way, and show you some work that I have just done with a spreader ditcher. They told me I could only have it five days, and Christmas and Sunday were in those five days. It did such good work that I wired the old woman she and the kids would have to get along without me Sunday and Christmas; that I could not have the spreader but five days and I was going to stay with the spreader. That spreader in five days did more work than 1,700 men." That is the way he expressed his appreciation of it, and on our road we are pretty enthusiastic.

Mr. Ringer:—I would like to call attention to the language of paragraph 5. It was not the intention to recommend against the use of the spreader car. The second sentence reads: "These machines may be used to advantage on lines of moderate traffic in ordinary material, but their use is not recommended on heavy traffic, single-track lines with frequent trains; nor is the use of other ditching machines recommended under similar conditions."

Mr. W. H. Penfield (Chicago, Milwaukee & St. Paul):—I was a member of the Sub-Committee that worked on this question and in listening to Mr. Ford it occurred to me that he is only talking of one class of ditching machines. The Committee, before preparing any conclusions or recommendation, went into the matter thoroughly, and they outlined here some of the machines that were reported as being in use on the various railroads in the country. The spreader cars that Mr. Ford speaks of are comparatively new on the majority of railroads, and I think the questionnaire that we sent out brought replies from but a few railroads that were familiar with them; at least the replies would indicate that they had not been used to any extent. I was in thorough accord with the Committee's conclusions or recommendations, and I think that these were borne out by what little data we could get as to the cost of ditching.

It was not the Committee's intention to in any way embarrass the users of spreader cars with ditching blades. We felt, however, that there were a good many things yet to learn about that class of ditching, and just what effect it would have on your ballast and your roadbed, and I do not think it would be a good thing for this convention to adopt some recommendation or conclusion here for ditching and limit it to spreader cars, because we all have ditching to do, and most of us at the present time are not equipped with machines enough to go around. Personally, I think there are a great many cases where hand ditching is the cheapest.

Chairman Ambrose:—I will let you into a little secret; the Sub-Committee members in their modesty hesitated to say it, but there is not a man on this Committee that does not want what Mr. Ford has suggested, but unfortunately the managements do not agree with him. We formulated this report, modified it, and present it in such a way so as to make it easy for them, because we felt that with this report to place before them, it would help us in getting the equipment.

Mr. Jenkins:—In making my remarks I did not have in mind the Baltimore & Ohio, but I had in mind the Long Island Railroad and the Harlem Railroad, where I think the traffic is fairly dense. However, there is one part of the Baltimore & Ohio System where there is a scheduled passenger train each way every 20 minutes.

Mr. Ford:—I don't think the Committee will ever get very far with their managements in the way of obtaining new machines for such work if the latter should get out the Manual of this Association and find confronting them a statement to the effect that a mechanical ditcher is not recommended for heavy traffic lines.

Mr. W. M. Camp (Railway Review):—I think the language of paragraph 5 is a little too sweeping, and that a little compromise in it might reconcile the two sides of this thing. The Committee says: "Their use is not recommended on heavy-traffic lines." Would the Committee be willing to substitute for those words, "their use may not be economical on heavy-traffic lines," and if they would do that, would that satisfy you, Mr. Ford?

Mr. Ford:—No, sir; it would not.

Mr. R. G. Kenly (Minneapolis & St. Louis):—I would like to suggest that in paragraph 5 the Committee consider eliminating the last three lines, from the word "but." We have had exactly the same experience as the Rock Island, not in such an extensive way probably, but the spreader car has come to stay.

The President:—Will that satisfy you, Mr. Ford?

Mr. Ford:—It may satisfy me, but the Committee should not be satisfied because it leaves their report without any punch in it. It seems to me that in view of its great importance the Committee ought to withdraw this report and then come back next year with a report that will be a credit to the Committee and a real benefit to the Association.

Mr. Penfield said that this is a new thing and, to some extent, he is right; all the more reason then why the Committee should wish to review the subject in the light of these modern means and methods and bring in an up-to-date report next year, especially as the personnel of the Committee is composed of men who have the ability and the knowledge to do this.

(The amendment was put to vote and carried on a rising vote.)

The President:—Now we have reached the motion to print No. 1 in the Manual.

(Motion put to vote and carried.)

Chairman Ambrose:—Subject No. 7, "Chemical killing of weeds and the removal of killed weeds from the roadbed," will be presented by the Chairman, Mr. Fisher.

Mr. S. B. Fisher (Missouri, Kansas & Texas):—So far as the Committee can ascertain, only a few of the larger railway systems of the country have yet tried to any extent chemical weed killing. Instead of sending out a general circular, your Committee has tried to collect information by personal solicitation and correspondence with those parties who have had charge of the work and knew the facts. The first reports that came in seemed to be along definite lines and your Committee hoped to draw some definite conclusions; later reports not only modified the earlier reports in many respects, but even contradicted them, so that the Committee has been confused to a certain extent about the facts, and has summarized the condition of its work as well as it could in their conclusions on page 421, which with the indulgence of the Association I will read.

The President:—This is to be received as information. Any discussion? If not, we will pass to the next.

Chairman Ambrose:—Mr. Curd will give you a short resume of his work and that of his Committee.

Mr. W. C. Curd (Consulting Engineer):—Your Committee took up this question and found that the subject was assigned to the Masonry Committee in 1917, and that Committee reported progress both in 1917 and 1919. There is a special committee now of several associations considering the matter. The work of this Committee was confined to the application and use of the pipe, and our conclusions are found on page

422, which we ask the convention to accept as information, and to await the final report of the Masonry Committee on the question of design.

The President:—This is to be received as information. Is there any discussion? If not, we will pass to the next.

Chairman Ambrose:—Subject 9, "The excessive cost of maintenance during the early period of operation," will be presented to you by Mr. Cunningham, Chairman of the Sub-Committee.

Mr. C. C. Cunningham (Chicago, Rock Island & Pacific):—Our subject is one that is being discussed by a Sub-Committee of the Presidents' Conference Committee. It is our thought to bring the matter to the attention of those of the Association who have no particular interest in valuation matters. The report contains some valuable information and also shows two forms which are of value in making a study of the subject. The report is submitted to you as information.

The President:—The report is to be received as information. Is there any discussion?

Mr. Wendt:—I note that this subject is entitled, "The excessive cost of maintenance." I desire to suggest to the Committee as well as the Board that the word "excessive" gives rise to a misunderstanding. There has been a great deal of discussion this last year regarding costs being "excessive." We have heard of the excessive cost of maintenance, excessive cost of land, excessive cost of other things. It seems to me that it is not appropriate to use the term "excessive cost of maintenance," because the public as well as members of other professions will interpret these words to mean unfair and unreasonable. What the Committee is intending to discuss, it seems to me, is the comparative cost, the relative cost, and I would suggest that the word "excess" and "excessive" be eliminated because they give rise to a false understanding. The sooner we get rid of these inaccurate expressions which give rise to a false understanding on the part of the public, the better it will be for the railroad profession.

I wish to bring another subject to the attention of this Committee: When you consider this question of the comparative cost of maintenance in the early days of operation, I hope that you will by some means differentiate the cost of this additional investment in capital goods from the cost of straight maintenance. Paradoxical as it may seem, it is possible to create an investment in capital goods through the maintenance account, and I hope the Committee will separate the cost of strict maintenance from the cost which is incidental to development and appreciation.

Chairman Ambrose:—The Committee is not responsible for the subject-matter. That will be given consideration.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—The Committee use the word "excessive," whereas the instructions read "excess." It makes quite a little difference.

Chairman Ambrose:—We stand corrected.

The President:—Any other discussion? If not, the Committee is dismissed with the thanks of the Association.

DISCUSSION ON ELECTRICITY

(For Report, see pp. 85-129.)

Mr. Edwin B. Katte (New York Central):—This year the Committee on Electricity was charged with reporting on nine subjects; three of the nine are controversial, and with regard to one of them there is some difference of opinion, even on the part of members of the Committee. In the absence of Mr. Kittredge, the Chairman of the first Sub-Committee, I will say that no revisions in that part of the Manual which comes within the jurisdiction of the Committee on Electricity are recommended this year.

The second subject, namely, electrical interference, will be presented by the Chairman of that Sub-Committee, Mr. Vandersluis.

(Mr. W. M. Vandersluis presented item 2, "Electrical Interference," pages 88-89.)

The President:—This report will be received as information. Is there any discussion? If not, the Committee will proceed.

Chairman Katte:—The next subject is water power. Mr. W. L. Morse, Chairman of the Sub-Committee, will present the report.

(Mr. Morse abstracted the printed report.)

The President:—The report of the Sub-Committee will be received as information, if there is no discussion.

Chairman Katte:—The next subject is "Electrolysis." In the absence of Mr. Martin Schriber, Chairman of the Sub-Committee, I will present the report.

(Chairman Katte then abstracted the report and said:)

The Sub-Committee on Electrolysis devoted its time during the past year to co-operating with the American Committee on Electrolysis. During the past year the American Committee on Electrolysis completed its report and it has been reprinted in Bulletin 244. You will find this report of considerable value as a book of reference. As it contains the latest information with regard to methods for mitigating electrolytic damage. The Committee wishes to recommend that the report of the American Committee on Electrolysis be accepted as information, and published in the Proceedings and in the Manual as valuable permanent engineering data.

(Motion put and carried.)

Chairman Katte:—The next subject (5), "Coöperation with the United States Bureau of Standards," is reported in Appendix D.

Chairman Katte abstracted the report and read the conclusions and recommendations on page 113.)

Since the Committee wrote this commentary there has been considerable activity in the matter of overhead wire crossing specifications. With the object of promptly bringing the A.R.E.A. specifications up to date. Your Committee have prepared an addenda to its report. The addenda is dated March 1st, and has been distributed by the Secretary.

This addenda is submitted as information; the changes are mostly corrections of obvious errors in the matter of voltage tests for insulators, also you will find that the structural engineers have reduced some of the wind loads and pressure. If you accept this addenda, it will form a part of the existing specifications. If you approve the further suggestion of your Committee, the entire specifications will be revised during the coming year, in fact the Committee is now working with that end in view. The effect of approving this addenda is merely to give you the benefit of the last work of the Committee, to bring the existing specifications more nearly in line with present practice for use during the interim. I move that this addenda be approved and made a part of the existing wire crossing specifications.

(Motion carried.)

The President:—I am sure the Association has confidence in the experts we have on this Committee.

Chairman Katte:—The next is subject (6), "Overhead transmission line construction." This report will be presented by Mr. Withington, Chairman of the Sub-Committee.

(Mr. S. Withington abstracted the report and said:)

We feel that the establishment of common standards for power line work and a reduction in the present number of types and kinds of construction is very desirable from an economic standpoint, and your Committee hopes to coöperate with other bodies to promote this result.

The subject of transmission line standardization is very active just now, as specifications are being considered by state public service commissions, as well as by various technical organizations. The National Electrical Safety Code, while it does not provide actual specifications, nevertheless contains a great deal of data which will be of value.

(Mr. Withington then read recommendation on page 115.)

The President:—The report is received as information, if there is no discussion.

Prof. S. N. Williams:—I wish, gentlemen, to express the high appreciation of the public for work already done in electrification of railways, starting possibly with the Chicago, Milwaukee & St. Paul in the West and the New York Central and New York, New Haven & Hartford in the East, also that to be done soon by the Illinois Central Railroad. Should a canal be constructed connecting the Great Lakes with the St. Lawrence river, while it will help Canada very largely, yet it will also help our Western States and develop a great amount of electrical energy.

Chairman Katte:—In the absence of Mr. Bassett, I will report on Item 7, "Clearances—Third Rail and Overhead." (Abstracting report.)

Chairman Katte:—On subject (8), "Collaboration with Committee XVI—Economics of Railway Location," in the absence of Mr. Brumley, Mr. Morse, Vice-Chairman, will present the report.

(Mr. W. L. Morse abstracted the report.)

The President:—This report will be received as information. Any discussion? If not, we will pass on to the next.

Chairman Katte:—Item 10, "Standardization." In the absence of Mr. Lowry, I will present the report.

(Chairman Katte abstracted the report and said:)

These specifications as written are the existing specifications of the A.S.T.M. Since the printing of our specifications Committee D-11 of the A.S.T.M. held a meeting on March 7th, and agreed to make a number of important changes in the two specifications. Your Committee this morning held a meeting and considered briefly these changes, and now do not recommend that the specifications as printed in the Bulletin be adopted. They wish to recommend that these two specifications be accepted as a progress report, and the subject continued. During the coming year close coöperation will be maintained with the A.S.T.M. Committee, also with the Signal Committee of this Association, and another set of specifications will be submitted. I move that these specifications, instead of being approved as recommended practice, be accepted as information.

The President:—If there is no objection, this portion of the report will be received as information.

Chairman Katte:—After the report was completed, the Board of Direction submitted another subject to the Committee, viz., "The protection of oil sidings from danger due to stray currents," and a supplemental report dated February 27th was distributed to you yesterday, therefore I do not expect you will wish to endorse these rules as recommended practice, but will wish to accept them only as information with a view to adopting the rules next year as recommended practice, if they prove satisfactory.

The President:—The report will be received as information.

Chairman Katte:—I move that the report of the Committee on Electricity, as modified at this meeting, be accepted.

(Motion carried.)

Mr. G. J. Ray (Delaware, Lackawanna & Western):—As a matter of information, I would like to get straightened out on the motion which was passed at the beginning of the Committee's report to place the entire report on Electrolysis in the Manual. Is that the intent of that motion?

Chairman Katte:—Yes, that was the intention. You will find that that report is really a book of reference. Only a limited edition was printed by the American Committee on Electrolysis. It was the idea of that suggestion that each of the various associations concerned in the preparation of the report would print it in their Proceedings—in our case in the Manual as well as in the Transactions.

Mr. Ray:—I think it should appear in the Annual Proceedings. We had a similar case yesterday and the matter was negative on account of the length and character of the report. This would make a very large addition to the Manual, 176 pages, and if we undertake to add to the Manual in this way we will get ourselves into trouble. I would like to see the former motion rescinded and this report placed in the Proceedings only.

Chairman Katte:—The reason the Committee recommends putting it in the Manual is that in effect it is a book of rules, it is a truly standard work, and we thought that the Manual was the proper place for it. The treatise represents the three or four years' work of some thirty or forty men, the best qualified in this country to prepare such a report, and it embodies the unanimous opinions of these men who represent every phase of the subject.

Mr. H. L. Ripley (New York, New Haven & Hartford):—We are loading our Manual to a point where it is no longer a handbook but has become a text book. This Association will soon have to face the question whether there must be a radical change in the composition of the Manual; whether we will not have to take out many of these specifications, etc., from the Manual, and print them either in separate volumes or in the Proceedings, and make reference in the Manual to them specifically—have references to them appear in the index to the Manual, so that a railroad Engineer who is looking for information on the subject will find it without being compelled to look through the Proceedings.

Chairman Katte:—It will meet the approval of the Committee on Electricity if the subject is indexed and cross-referenced in the Manual, so that an Engineer looking up "Electrolysis" will readily find it in the Manual and be referred to the given issue of the Proceedings in which the report can be found.

Mr. Ray:—There is no doubt about the value of this material, but it is an exceedingly extensive report, and I think much information is contained in it that we have not heretofore included in the Manual. We have got to determine whether such information is going in the Manual. I did not realize the vote meant the whole report.

Chairman Katte:—I move that portion of the motion be reconsidered.

(The motion was duly seconded and carried.)

The President:—The original motion is before the house to place the report in the Manual.

Chairman Katte:—I move that the Report on Electrolysis be indexed in the Manual and cross-referenced. Also that it be published in the Proceedings.

(The motion was carried.)

The President:—The report is received on that understanding, and the Committee is dismissed with the thanks of the Association.

DISCUSSION ON RECORDS AND ACCOUNTS

(For Report, see pp. 431-445.)

Mr. H. M. Stout (Northern Pacific) :—The report of the Committee on Records and Account is given in Bulletin 242, pp. 431-445.

The first subject is Revision of the Manual. We submit a number of changes in the definitions as they now appear in the Manual.

I move that the revised definitions be approved and substituted for those appearing in the Manual.

Mr. Edwin F. Wendt (Consulting Engineer) :—The definitions which now appear in the Manual have been there for over fifteen years. They were formulated very largely by the late Walter G. Berg, Chief Engineer of the Lehigh Valley Railroad, than whom there was no greater authority on definitions. When they were adopted they were thought to be as near perfect as they could be made. I should like to have the Committee explain what difference there is between the definitions now in the Manual and the proposed revised ones.

Chairman Stout:—In the case of the first definition, "Accounts," the changes recommended are, first, the elimination of the comparative costs. It does not seem that the word "account" as used in common practice has particular reference to comparative costs. And, second, the elimination of the word "various" in connection with the classes of expenses.

In the case of the second definition, "Ledger Accounts," the chief criticism which presented itself in making a study of the definition already given in the Manual was the pleonasm at the beginning of the definition. You will notice that without altering the fundamental idea in the use of the term greater simplicity has been attained in the revision over the present text. It seemed to us we should get more directly to the heart of the idea.

(Motion carried.)

Subject 2, "Cost-keeping methods and statistical records." I will report, in the absence of Mr. Bortin, Chairman of the Sub-Committee, studying this subject, that the matter is still under discussion and certain data is being collected from the various railroads. This data is necessary in order to complete the study of the work, therefore this Sub-Committee offers a progress report only.

Subject 3, "Forms for recording data for keeping up to date records of property changes and valuation of railroads." In the absence of the Chairman of the Sub-Committee, Mr. Henry Lehn, I will ask Mr. E. B. Crane, a member of the Sub-Committee to present the report.

(Mr. Crane abstracted the report.)

Chairman Stout:—I move the three forms just referred to, together with the specifications and instructions, be accepted and published in the Manual.

(Motion carried.)

Chairman Stout:—Subjects 4 and 5 are still under discussion by the Committee, and only progress can be reported at this time.

Subject 6, "Conventional signs for architectural details." Mr. Blanchard, Chairman of the Sub-Committee, will present that portion of the report.

Mr. A. M. Blanchard (Grand Trunk):—The report is divided into two parts, viz., Exhibits D and E. The first deals with signs used by the electrical trade. It was found that these conventional signs had already been adopted by national associations and published in their latest handbook, and the Committee feels these should be adopted and published in the Manual as good practice.

Exhibit E is a list of architectural symbols gathered from various sources. It was found there were a large number of architects using the same signs.

Chairman Stout:—I move the electrical symbols shown as Exhibit D be accepted and published in the Manual.

(Motion carried.)

Chairman Stout:—The architectural symbols under Exhibit E are offered as information.

Subject 7, "Methods for recording and accounting for the determination of proper allowances for maintenance of way expenses due to increased use and increased investment." This is a new assignment and a Sub-Committee of this Committee has begun work in conjunction with a Sub-Committee of Committee XXI studying a kindred subject. The Committee reports progress.

Subject 8, "Future work," the Committee gives its recommendations for future work under that caption on page 432.

The President:—The same will be received as information. This completes the work of the Committee and it is excused with our thanks.

DISCUSSION ON SIGNS, FENCES AND CROSSINGS

(For Report, see pp. 447-482.)

Mr. Maro Johnson (Illinois Central):—The report of your Committee on Signs, Fences and Crossings appears in Bulletin 242.

The first subject, to which your attention is directed, is "Location of signs."

I move the adoption of the conclusion given on page 448, relating to the location of signs, and that the tabular statement be printed in the Manual.

(Motion carried.)

Mr. A. V. Brown (Lake Shore Electric):—On page 453 the highway crossing sign for the purpose of warning the public is not the same which was adopted by the Association several years ago.

Chairman Johnson:—It is not the intention to differ from the sign shown in the Manual and adopted some years ago.

Mr. C. E. Lindsay (New York Central):—On page 449, the Committee says: "The Committee believes it would generally be better to adopt a uniform distance for all signs, wherever possible, rather than vary it for different classes of signs, the main consideration being safety for employees, which condition is controlled by distance from the track."

I agree with that. There are some signs which have been obscured by other signs not necessary for the engineer, and they should be placed a certain distance from the track, otherwise there may be some conflict.

Mr. J. L. Campbell (El Paso & Southwestern):—I suggest that the lettering shown on the illustrations should be the same as that shown in the Manual.

Chairman Johnson:—The third subject is "Highway Grade Crossings." The Committee has not concluded its work on this subject. The next subject, No. 4, is "Substitutes for wood crossing planks." This part of the report will be presented by Mr. Batchellor.

(Mr. Batchellor abstracted the report and said:)

The report is offered as information.

The President:—It is a splendid report and it will be received as information.

Chairman Johnson:—The next item is subject 5, "Plans and Specifications for Concrete Fence Posts." This will be presented by Mr. T. E. Rust, Chairman of the Sub-Committee.

Mr. T. E. Rust (Waterloo, Cedar Falls & Northern):—As regards specifications, inasmuch as our Committee is not asking that these specifications be adopted, but is only submitting them for information, I will not read them, but will make a few comments that may make them clearer to the members.

In drawing these specifications the Sub-Committee faced two problems—the first one was, should these specifications include specifications for the concrete from which the posts were to be made? We decided that they should, for several reasons. The fact that the Committee had been asked to draw specifications indicated that they should include the concrete specifications, otherwise all that would be left would be the conclusions adopted by the Association some years ago.

In addition to that, there should be a limit to the references in the specification to other specifications. If we were simply to refer to some concrete specifications it would be necessary for the member to refer back to such specification, and similarly to a specification for reinforced steel, cement, cold drawn steel wire, etc. If this Committee at some later time were to adopt a specification for right-of-way fence using concrete posts, the member who wanted to look up these specifications would have to refer back to the specifications for concrete posts, and also to the specifications for concrete, wire, cement, etc. Therefore we thought it best to include specifications for concrete.

We have decided that we will follow the tentative specifications recently proposed by the Joint Committee of the various engineering societies. This seemed reasonable to the Committee, because it is proper to suppose that they would represent the last word in concrete specifications. Since we drew these specifications, I understand that the tentative specifications of the Joint Committee has received a good deal of criticism, largely, if I am not mistaken, criticism of the specification which described the strength which concrete should have, rather than describing the ingredients from which it should be made. However just that criticism may be, I do not think it applies to concrete fence posts, for the reason that before a post factory is set up on a railroad, the available aggregates that the concrete can be made from are known and it can be determined in advance what the strength of the concrete will be for various proportions of cement and aggregate.

I will not refer to these specifications any further, other than to say that it is hoped that the members will criticize them freely here and by correspondence later.

There is one other thing I want to refer to briefly, and that is on page 475. There might possibly be some misapprehension of the statement made there. One might get the impression perhaps that the posts heretofore manufactured by the railroads in the "U" shape were nearly all reinforced with flat bars, and that they were unsatisfactory. I believe that proper reinforceing and proper methods of manufacture are now being used, and that a number of railroads are finding these posts satisfactory.

On page 474 I want to call your attention to a slight error in the table of information about posts. The Committee is not recommending a post of 13,915 sq. in., so that the comma in that line should be a period.

The Committee simply recommends that these plans as well as the specifications be received as information.

The President:—It will be so received.

Chairman Johnson:—Subject No. 6, "Comparative economy of wood, steel and concrete fence posts." The Committee wishes to report progress.

Subject No. 7, "Recommendations for future work," will be found on page 448.

The President:—This concludes the report of this Committee. The Committee is excused with the thanks of the Association.

DISCUSSION ON WATER SERVICE

(For Report, see pp. 483-527.)

(In the absence of the Chairman, Mr. A. F. Dorley, the report was presented by Mr. C. R. Knowles, Superintendent Water Service, Illinois Central Railroad.)

Mr. C. R. Knowles (Illinois Central):—Nine subjects were assigned to the Committee, and report is made on eight of these subjects.

(Mr. Knowles abstracted the first subject, Revision of Manual, on page 486, and said:)

I move that the report of the Committee outlined on page 486 be accepted, and that the definitions be adopted for inclusion in the Manual.

(Motion duly seconded and carried.)

(Mr. Knowles abstracted Appendix B, pages 487-489, and said): This is submitted as information.

The President:—It is received as information.

Mr. Knowles:—There is no report on subject No. 3, "Specifications for contracting water service work," other than one of progress.

(Mr. Knowles abstracted Appendix C, "Effect of local deposits on pollution of surface and shallow well water supplies," and said):

It is moved that the report on this subject be received as information.

The President:—It will be so done.

(Mr. Knowles abstracted Appendix D, page 493, and said):

This report is submitted as a progress report and as information.

The President:—It will be received as information.

(Mr. Knowles abstracted Appendix E, page 498, and said):

It is moved that the specification be approved for publication in the Manual.

(Motion duly seconded and carried.)

(Mr. Knowles abstracted Appendix F, page 508, and said):

It is moved that this be accepted as information.

(Motion duly seconded and carried.)

Mr. J. L. Campbell (El Paso & Southwestern):—In our experience we find the centrifugal pump an economical means of lifting water up to 200 feet. In one case the lift is 400 feet, but we find that not economical and this installation is being replaced by deep well double acting plunger pumps.

(Mr. Knowles abstracted Appendix G, page 514, and said):

These specifications were approved by the Water Service Committee and the Committee on Standardization and are submitted for your approval with their recommendation. The specifications for pipe are the standards of the American Waterworks Association as adopted by that association, May 12, 1908, and are generally regarded as the manufacturers' standards. They have been widely used throughout the United States and have been adopted as standards by practically all municipalities and railroads throughout the country. It is moved that these specifications be adopted for publication in the Manual.

The President:—May I ask if the American Waterworks Association collaborated with your Committee when these standards were adopted?

Mr. Knowles:—They did not. They gave us permission to use them.

Mr. C. E. Lindsay (New York Central):—Will the Committee consent to substitute the word "specification" for the word "standards" on page 514 in the large heavy type, "Specification for cast iron water pipes" and "Specifications for hydrants and valves?"

Mr. Knowles:—Yes, sir; the Committee will accept that change.

Mr. Lindsay:—And omit "standard" from the word "specifications" following?

Mr. Knowles:—Yes, sir.

Mr. Lindsay:—Similarly on page 520 omit the word "standard."

Mr. Knowles:—The Committee will be glad to accept that change also.

(Motion put to vote and carried.)

(Mr. Knowles abstracted Appendix H, page 527, and said):

It is the desire of the Committee to coöperate with the universities in the study of this work, so that the results will be consistent, and not in conflict with actual practice and experience. This report is submitted as information.

Mr. D. A. Steel (Railway Age):—Just a word in regard to the fourth paragraph of Appendix H, concerning the investigation made by me at the University of Montana in 1920. I do not wish to give the impression that I am critical about the Committee's report on this work, for I am grateful to know that it saw fit to take notice of it, and I realize also that the desire of Committee was only that of bringing out the interest on the part of the universities of the country to coöperate with the engineering forces in solving their problems. But in the interest of the work itself I want to say a word, as I am afraid that some of the phraseology used by the Committee will otherwise have a damaging effect upon the character of the original report.

First let us refer to the statement in the Committee's remarks in which reference is made to the original report as a study of the electrolytic phase of pitting and corrosion. As to the words, "electrolytic phase," if the Committee was simply using the words in the same sense as one would say historical phase or the like, I have no comment to make, but I think the inference which would be drawn by almost any one in reading the statement casually would be that the Committee referred to the report as an exposition in support of the electrolytic school of thought as against any other school of thought on corrosion. The report, however, should not be considered in this light, for there was no intention in carrying out the investigation to take sides, the aim throughout the whole work being rather to bring forth some very interesting and significant observations in connection with the phenomena of pitting so that all parties concerned might more fully appreciate the nature of the problem and be willing to carry on the work of study.

Now, to refer to the last statement of the Committee which says that "the results secured are not sufficiently definite for authoritative publication and it is suggested that further investigation be carried out along these lines"; I am afraid this statement even more than the one above creates a wrong impression regarding the work by reason of the inference it leaves that the words express the conclusions made by the Committee rather than reiterate, merely, the remarks made in the original report. In this report, as its reading will make apparent, there was no attempt to establish any conclusive results as to the methods of preventing corrosion, the effort being merely to disclose in an organized way some very significant observations and to indicate a promising course of study to take in future investigations.

Mr. Knowles:—The objections raised by Mr. Steel do not seem to be very serious, and I think with his explanation included, it will be clear to all who read it.

I am very sorry Mr. Dorley could not be here today. I have had several meetings with Mr. Dorley during the past year, and I know it was his intention to make a few comments in general on the subject of water service. I have a few ideas that I have jotted down, which with your permission I will read.

A water supply, ample in quantity and of satisfactory quality, is one of the essential requirements for the successful operation of a steam railroad.

A survey of the field in this country indicates that a conservative estimate of the annual water consumption on American railroads is approximately nine hundred billion gallons. In the neighborhood of 14,000 water stations are required to supply this amount of water, involving a very large initial investment. The annual expenditure for operation and maintenance is in excess of one hundred million dollars. While this figure represents an important item of expense in railroad operation, it is small in comparison to the expense involved from the effect on locomotive upkeep and operation, caused by use of unsatisfactory or inadequate supplies. And the time will come when the extravagance of water waste and scale in boilers will not be tolerated.

There appears to have been but little progress in the development of suitable organization to handle this important feature of railroad operation. It is a significant fact that where special attention has been given this subject, very satisfactory economies have been effected together with improvement of the property and power.

It is again desired to call the attention of the members of the Association to the possibilities of the Water Service Organization as approved last year for publication in our Manual of recommended practice.

The President:—This completes the work of the Committee, and they are dismissed with the thanks of the Association.

DISCUSSION ON UNIFORM GENERAL CONTRACT FORMS

(For Report, see pp. 529-539.)

Mr. W. D. Faucette (Seaboard Air Line) :—We only have two main things to present. It is our policy each year to present one completed document, and this year we so present it. We also have corrections in the Manual.

In the absence of Mr. Dillenbeck, Chairman of the Sub-Committee, I will present his report.

(Abstracting Appendix A, page 534, Section 1.)

We move that this correction be made.

(Motion duly seconded and carried.)

(Reading Article 2, page 534; also Article 3. Chairman Faucette abstracted Appendix B, page 536, and said) :

There seems to be a great deal of difference among ourselves as to a proper liability clause in this tentative report, and we were unable to come to any final conclusion. In this connection it is proper to say that this Committee has been in contact with the American Railway Development Association, who are also interested in the subject of our standard contract forms, particularly the "lease agreement for industrial site," and under the direction of this Association we will continue our contact with the Development Association, and report to you next year what we have developed, and how close we may come to an agreement, and submit recommendations, if required.

Before I present for final action the report of the Committee, by Mr. J. C. Irwin, found on page 536, I wish to call attention to our report on pages 530-32. Briefly stated, the President of your Association delegated me to attend a conference in Washington in December, called by the Associated General Contractors of America. General Marshall, who is to address us this evening, is the General Manager of that association.

I went as delegate for your Association and we spent two very profitable days and there was made a report of about 375 typewritten pages to your President. It is the purpose, so far as possible, to create a national construction contract applicable to all forms of construction industry in this country, and as far as possible get such a contract adopted by these leading national associations so it will have a national import, and the strength of their approval.

The question arose about an arbitration clause in such a construction contract. It was the unanimous opinion of the delegation in Washington (with the exception of your representative) that in such a national contract there should be an arbitration clause. That arbitration clause as we understood it then, and now, was to be in lieu of the decision of the Chief Engineer as umpire. Our standard form of contract (in the Manual) make the Chief Engineer the arbitrator and umpire of the decisions between the contractor and the railroad company.

We are now considering as to whether this Association will or will not embrace such a national arbitration clause. If we do not embrace it, our representation in connection with the proposed standard contract form may have to be withdrawn, but we do not know yet just what attitude we will take. We should approach that subject with much care. A great many of the leading minds of the country today are in favor of some kind of arbitration, and are in favor of some arbitration clause, and they have presented their views to the Washington conference. There is equally a school opposed to such arbitration in construction contracts as strongly as possible.

We had a profitable meeting today with Mr. Onward Bates and General Marshall, and other gentlemen, and we assured them that this Association would continue to have a representative at the further conferences at Washington, with a view to seeing how far we could go towards creating with other societies, etc., a national contract which might be accepted in lieu of the present construction contract of the A.R.E.A. as now appears in our Manual. We will report what we do. In the meantime, your Committee on construction contracts of this Association will take under advisement this particular question of an arbitration clause, and will, as soon as practical, make a report, and therefore you may be called on at your next annual meeting to decide whether this Association will accept an arbitration clause in lieu of the Chief Engineer being an umpire, as now is the case.

It is to be applicable to all forms of industry represented by everyone who administers construction work. The idea is to have a saleable and standardized contract which has been adopted by these national associations, and has the weight and approval and the authority of these national associations. It is therefore apparent that if this Association should decide to withdraw from it, the contract, if created, will lose the strength of this coöperation. The American Institute of Architects has adopted an arbitration clause. My attitude is one of absolute neutrality. I stated that the Association could not through me now take a position for or against it, and that is my position today. I will in a short time put the matter before your Board of Direction, through our Committee, and you will have the report to consider.

This is therefore a matter of much importance and involves the idea as to what this Association thinks should be the relation of the Chief Engineer to the railroad contractor. Such relation means the railroad's attitude toward the contractor; whether the Chief Engineer should remain the umpire or not. It requires careful thought.

Mr. Irwin will present the report on "Form of license for wires, pipes, conduits, and drains on railway property."

(Mr. Irwin abstracted the report.)

Chairman Faucette:—I move that the proposed form be adopted and printed in the Manual.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I assume, of course, that this Committee has been in touch with the Committee on Electricity. Are you satisfied there will be no objection raised by that Committee?

Mr. J. C. Irwin (Boston & Albany):—This Committee has conferred with the Committee on Electricity and the Committee on Roadway and they are in agreement with it.

(Motion carried.)

Mr. Irwin:—The further work of the Sub-Committee consists of a typical form of agreement for trackage rights, which is based on agreements of thirty-four roads throughout the United States and Canada, and we have started on the preparation of such a typical form and propose to present such form next year.

The President:—This concludes the report of the Committee for this year, and the Committee is excused with thanks.

DISCUSSION ON MASONRY

(For Report, see pp. 541-574.)

Mr. J. J. Yates (Central of New Jersey) :—Of the assignments to your Committee, reports are made on subjects 1, 3, 6 and 7.

On subject 2, the design of concrete and reinforced concrete structures, as developed by the Joint Committee on Concrete and Reinforced Concrete, no recommendations are made at this time. The Joint Committee report is open for discussion, but we are not in a position at this time to make any recommendations.

On subject 4, the question of causes of failures of certain concrete structures, the Committee has done a great deal of work, but we are not ready to make a report.

On subject 5, the question of distribution of loads through ballast, etc., much work has been done in the way of obtaining data, and we hope to make a report on this subject during the coming year.

On subject 6, a tentative specification for concrete and reinforced concrete has been placed before the membership of the Association, and I will have something to say on that a little later.

The conclusions of the Committee are contained on pages 541-2. The first is revision of the Manual, which is contained in Appendix A, pages 543-44, and the report will be presented by the Chairman of the Sub-Committee, Mr. Lacher.

Mr. W. S. Lacher (Railway Age) :—The first matter which the Committee has to offer is the revision of the specification for Portland cement. This specification was adopted by the Association in 1917, and is the product of a joint committee representing a number of interested associations.

This specification provides a maximum residue on a 200-mesh screen in the test for fineness of 22 per cent. In the previous specification, which is the one that appears in the 1915 Manual, this allowable residue was 30 per cent. This greater refinement in the requirement of fineness, namely, the reduction in the allowable residue from 30 per cent to 22 per cent, was felt by the manufacturers to be a rather severe change, and they requested that they be allowed a tolerance for a short period, in which to readjust manufacturing operations. As a consequence there was included in the specification at that time the paragraph which we present on page 542 of the Bulletin. It is felt now that sufficient time has elapsed so that this tolerance may be eliminated.

Chairman Yates :—I move the adoption of the recommendation of the Committee that paragraph 36 be omitted from the specification for Portland cement.

Mr. A. F. Robinson (Santa Fe) :—I do not understand paragraph 36 exactly. I would like to ask what provision there is made in that specification for fineness. Is it not 22 per cent flat?

Mr. Lacher :—Yes, in the old specification.

Mr. Robinson:—In the A.S.T.M. specifications as they are in use it stands 22 per cent flat without any modification, does it not?

Mr. Lacher:—Yes, the tolerance has been withdrawn by the other interested associations.

Mr. Robinson:—You mean from the present tolerance?

Mr. Lacher:—Yes.

Mr. Robinson:—The 22 per cent still stands?

Chairman Yates:—I might explain that this Association has not passed on the question of eliminating the tolerance clause. The A.S.T.M. and the Government have done this with their specifications as they now appear. The revised specification has been approved as a tentative standard by the American Engineering Standards Committee. It is in line with that action and with the action of your representatives on the Committee on Standard Specifications for Portland Cement at the time they were prepared that the recommendation to omit the tolerance clause is made.

Mr. Robinson:—What I was trying to get at is, have we anywhere else in these specifications a notation covering the fineness at 22 per cent?

Chairman Yates:—We have.

Mr. Robinson:—All right.

(Motion carried.)

Mr. Lacher:—The next matter given in Appendix A relates to a number of additions and changes offered to the specification for concrete and reinforced concrete, which were adopted by this Association in 1920. Because of the work of the Joint Committee it is felt that we might avail ourselves of the benefit of certain progress which that body has made by introducing certain additional clauses in our specification for concrete, so that this specification may be kept in line with the advance in the art. In this connection there is paragraph 11 on consistency. It is the feeling of the Committee that this should be modified so as to provide for the use of the slump test, and therefore we offer paragraph 11, in three sections, A, B, and C, appearing on page 543, as a substitute for the present paragraph 11 in the specification.

Chairman Yates:—I move the adoption of the recommendation for insertion in the Manual.

The President:—Mr. Yates, will you please explain where you desire to start paragraph 11 (a)?

Chairman Yates:—The matter to which we refer is at the bottom of page 543, under the title: "For paragraph 11, on Consistency, substitute the following:" The matter is contained in three paragraphs—11 (a), (b), (c).

The President:—I suggest that the Chairman of the Committee read these three paragraphs.

(Chairman Yates read the paragraphs.)

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis):—I would like to hear a statement as to whether, if we adopt the changes proposed by the Committee in paragraph 11, the specifications as then amended will agree with the Joint Committee's tentative specifications. I note that the Committee on subject 6 mentions the progress report of the Joint Committee, but does not recommend any action on it, and Mr. Lacher says that the changes proposed here are to make the specifications of this Association agree more nearly with the Joint Committee report.

I am wondering if it is worth while to make these few changes at this time, if there is a probability of the early adoption of the Joint Committee report as a whole?

I shall be glad to hear from the Chairman of the Committee just what the situation is on that point, and when we may expect action on the Joint Committee's specifications.

Chairman Yates:—The purpose of this change is to provide for the slump test. We are not attempting now to make our specification agree with the Joint Committee's specification. The only change here is the addition of the slump test to our specification, which is one of the items that the Joint Committee seems pretty well agreed on, and our purpose is to give the members of this Association the benefit of that recommendation now. The slump test, as a control test, we believe, is making good. It is not a measure necessarily of the strength of concrete, but a measure of the consistency and a guide to the man in the field, and we think it is desirable at this time that we provide this test.

There will, I hope, be a discussion on the Joint Committee's report later.

(Motion carried.)

Mr. Lacher:—The remarks which Chairman Yates has just made with regard to the slump test apply also in regard to the Committee's feelings on the test on organic impurities in sand, and we offer the paragraph on the top of page 544, introducing this test for the impurities in sand and referring to the details of the test which are introduced as information on the insert between pages 548-549. It is felt here also that the specifications should be adopted so as to obtain the benefit of this test.

Chairman Yates:—I move the adoption of this recommendation for insertion in the Manual.

(Motion carried.)

Mr. Lacher:—The specifications as now adopted contain no specification for wire reinforcements, corresponding to that for bar reinforcements. Unfortunately, the Committee is not in position to offer a specification for wire reinforcement for adoption, but wishes to add to the specifications, as a matter of information, a reference to a specification for cold-drawn steel wire for concrete reinforcement, which the user of the specification may take such advantage of as he may wish.

It is believed that this information will be welcomed by the user of the specification and we therefore offer the footnote to Appendix B, as shown on page 544, it being the idea to add this to the specification which appears on pages 545 and 546 as an appendix to the specification.

Chairman Yates:—I move the adoption of the footnote, "Tentative Specification for Cold-drawn Steel Wire for Concrete Reinforcement," referring to Appendix B.

The purpose of this footnote, as Mr. Lacher says, is to give the members of the Association information so that they can use this specification for cold-drawn steel wire for concrete reinforcement. There is none in existence, and this is a tentative specification only and is up for adoption now by other associations. There has been quite a demand for specifications of this kind, and we believe that our membership should have the benefit of this information.

The idea is to have the footnote placed in the Manual in the proper place under reinforcement, and that the specification itself be placed in the Proceedings, and a reference of the footnote refer to the Proceedings for the time being.

(Motion carried.)

Mr. Lacher:—During the war the users of concrete reinforcement were often greatly embarrassed by the inability to obtain materials and the War Industries Board, in order to expedite the manufacture and delivery of reinforcement, took upon itself the standardization of reinforcement sizes, or rather the reduction of the number of sizes to be used, and adopted certain sizes as standard.

It is believed by the Committee that the use of reinforcement bars could well be restricted to the sizes then established as standard, and we present on page 544 a table of these standard sizes with the recommendation that they be included in the Manual.

Chairman Yates:—I move the adoption of the matter under "Include under section on Steel Reinforcement the following": which appears in the middle of page 544, for insertion in the Manual.

(Motion carried.)

Mr. Lacher:—The present specification makes no reference to the spouting of concrete. This may perhaps be explained by the failure of the Committee which drew up the specification to agree on that point. It is the opinion of the present Committee that the user of the specification has a right to some information, to some of the best thought, at least, on the subject of spouting, and for that reason the Committee at this time submits a specification for the spouting of concrete, this being the clause that the Joint Committee has now in its tentative specification. This clause does not say that spouting may be done. It still puts the matter up to the Engineer on the job, but if the Engineer decides that he does want to permit spouting of concrete, this clause gives him a specification under which that may be done.

Chairman Yates:—I move the adoption of the clause at the bottom of page 544 of Bulletin 242, relating to "spouting." This is for insertion in the Manual.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I should hate to see that part of the report go into the Manual at this time. As I understand the situation the Committee does not recommend and will not recommend to the Association at the present time the adoption of the Joint Committee's report. This clause is to bring our specifications up to conform to the joint report. I think some of us do not yet agree that we should adopt the joint report, and until that is done I hardly see the necessity of putting into our specification a clause which stamps our approval on spouting, because that clause says with the approval of the Engineer, and it puts the stamp of approval on it. I am opposed to that for several reasons. In the first place, I do not believe that the consistency required in the report of the Joint Committee can be fulfilled in the manner indicated in this clause, therefore why should it be part of the report?

I therefore wish to make an amendment to the motion, that this clause be inserted merely as information for the present, and not inserted in the Manual.

Chairman Yates:—In answer to Mr. Ray I will say there has been a demand on the Masonry Committee for a clause on spouting. We have had many discussions on this subject, both in the Joint Committee on Concrete and Reinforced Concrete, and in the Masonry Committee itself, and this clause appears to meet that demand. It is the best we can do at the present time. It agrees quite closely with the Joint Committee's report.

(Amendment put to a vote and carried.)

The President:—The motion now before the meeting is that the information be received as information and published in the Proceedings.

(Motion carried.)

Chairman Yates:—The next conclusion is that of Appendix B, to be received as information.

The next is that of Appendix C, to be received as information.

There has been presented by the Joint Committee a tentative report on Standard Specifications for Concrete and Reinforced Concrete. It was submitted to the organizations composing the Joint Committee on June 4, 1921, and it is open to discussion for one year from that date before it goes back to the Committee. We have obtained some discussion, but the Committee feels we want much more. The Committee has no comment to make at this time, but we would like to hear from the Association in the way of discussion of this report. It is contained in pamphlet form, issued by our Association six or seven months ago.

Mr. Ray:—I do not wish to take the time of the convention to discuss the report at this time, but I would like to call the attention of all concerned to the importance of this report. This Association is going to be called upon in another year to pass on this joint report or this tentative report which is now before us, and it is of the utmost importance that every man in the Association study that report and be prepared to submit to this Committee his conclusions and recommendations with respect to it. I merely get up at this time to call your attention to one or two very important features of it, so that you will discuss them.

The suggestion that the contractor will be required to make concrete which will meet definite requirements as to strength is an all-important and far-reaching proposition. My own thought is at this time, after looking it over quite carefully, that it will mean a very material increase in the price of concrete where it is put in under that specification. I have during the past season been carrying on a few tests in an experimental way in actual practice to see what we could do ourselves in meeting the requirements of that specification. I have been amazed to find out how difficult it is for us to do it. If we cannot do it ourselves, how can we expect the contractor to know what he does when he bids on your work? If we have a specification on concrete which makes it almost impossible for the contractor to tell what he is figuring on, he is going to add a good big percentage to the proposition when he submits it, or else he will run a chance of going broke on that job.

I am not criticizing this report in detail, and do not intend to, but merely make these remarks to call your attention to the important point that we should consider it carefully and come here another year prepared to tell the Committee, or to submit to the Committee in the meantime in written discussion what we think of the report. I hope the Association will do that.

Chairman Yates:—I would like to call attention to the fact that under the rules of organization this Committee's discussion is closed by June of this year, and the Committee would like to have written discussion prior to that time so that we can have your help in getting some of these clauses modified or changed. I might say also in justice to the Committee that we are not all in accord in this report. It is a preliminary report, and there is no doubt there will be many modifications and changes, and we want the benefit of discussion on this matter.

The President:—That ends the report of this Committee and they are dismissed with the thanks of the Association.

DISCUSSION ON RAIL

(For Report, see pp. 621-667.)

Mr. G. J. Ray (Delaware, Lackawanna & Western) :—Please turn to page 636, recommended practice for inspection of steel rails. I wish to discuss this feature of the report first, for the reason that it is the only part of the report which we recommend to the Association for insertion in the Manual as recommended practice. The latter part of this Appendix B, commencing with "Methods of inspection of steel rail," on page 637, is merely included as information, to give the Association a general idea of the manner of inspection by various railroads, and some slight discussion on that subject, so that all we are asking you to do at this time is, and I make a motion to that effect, that the Association approve for insertion in the Manual that part of the report under "Recommended practice for inspection of steel rails," contained on page 636 and the top of page 637.

Mr. C. W. Gennett, Jr. (Robert W. Hunt & Company) :—I feel that it is proper to call attention to the fact that one of the requirements, that regarding the loading of rails of one heat in the same car, is liable to be very difficult of execution without the full consent and coöperation of the manufacturers. I merely make that statement because I think I can foresee some difficulty in handling it unless the manufacturers consent to that being done.

Chairman Ray:—Just what paragraph do you refer to?

Mr. Gennett:—Section 5, first paragraph.

Chairman Ray:—That does not say that, does it, Mr. Gennett? I will read the paragraph so all will understand what we are talking about. (Read paragraph 5, page 636.)

I think that this is misunderstood. It does not require that every heat shall be loaded separately.

Mr. C. E. Lindsay (New York Central) :—I have no difficulty in following along with the Committee on the duties of inspectors until I get down to the latter part of Section 6. Prior to that time the instrucions are imperative. Then they begin to take in the permissive, that is, "The office to which the rail inspection force reports should keep a record." It seems to me there should be another caption in there, and the word "shall" inserted in place of the word "should."

Chairman Ray:—If Mr. Lindsay will indicate what he wants, the Committee will consider it.

Mr. Lindsay:—The second sentence of Section 6, I think, should be taken out of that section and put under a general caption at the close of the specification. The next paragraph on the subject of Rail Inspectors should also be under a general caption. The instructions regarding the acceptance of heats is a part of the duty of an inspector, and it should be properly included under Section 6. The final sentence in the specification, reading: "The inspectors cannot be too careful and must exercise good judgment and all possible tact," is a rather curious specification, but could properly be left in Section 6.

Chairman Ray:—It could not be objected to as not being good practice?

Mr. Lindsay:—No, sir.

The President:—There is no motion before the house except the original one. I think the Committee can rearrange that to your satisfaction, Mr. Lindsay.

(Motion put to vote and carried.)

Chairman Ray:—At the time the report was presented to the Association, the statement was made that we expected to have a revision of the specification to present to the Association at this time. Since this report was prepared, the Committee has had two meetings. They had a joint meeting with the Rail Manufacturers' Committee in an effort to agree on tentative specifications which could be presented to this Association for consideration. During the past season the Committee has paid particular attention to mill practice at various mills, and as a result of the studies which have been made the Committee thought best to prepare a new specification or to revise the old specification with a view of eliminating, as far as possible, segregated steel. Those of you who have read the article entitled "Mill Practice," on page 621 of the report, will understand what I mean when I say that we have felt it advisable to get the manufacturers to produce the steel in the furnace as far as possible, rather than in the ladle or in the ingot. With that in view we prepared a specification for consideration and discussion by the manufacturers.

On February 24th we met with them and spent the day in discussing the various features of that tentative specification. It was not all peace in that meeting, but I think we accomplished something. We at least got together on certain features of the specification. The manufacturers, however, took the position that we were suggesting certain practices of which they could not foretell the results, and for that reason they would not agree with us to proceed on such a specification and if anything were done it should be with a view of testing out what we had suggested before it was made a general specification. Many members of the Committee felt the same, that we could not expect to start any radical changes until we knew pretty well what we were doing, so what we finally determined to do was to agree so far as we could, and ask the manufacturers to submit to us definite suggestions about certain other clauses referring to mill practice before the time of this convention. They did that, and during the convention we have had another meeting of our Rail Committee, and have ironed out certain differences so that we are in this position today.

We have before us another *tentative specification*. I want to make it plain that this specification is a *tentatitve* one, because it has not been passed on by the Committee. It is an experimental specification, if you please, that we believe will accomplish certain results. The main feature of this tentative specification is, as we believe, an effort to get away from segregation. In eliminating the nick and break test from the specifications we feel that we are giving the manufacturer a little more chance to get away from segregation than is possible under the present specification.

I will say frankly that some of the members of the Committee were not in favor of this change. They think it is a mistake to eliminate the nick and break test. It should not be overlooked that we do not want to get steel which is piped, but the majority of the Committee is of the opinion that if the manufacturer is permitted to roll rail from steel which tends to piping rather than segregation, we will get a safer rail for our tracks than much of the badly segregated steel we now get.

One of the things I would like to bring before the Association, and I believe the Committee as a whole feel as I do about it, is that we believe there is a general impression about piped rails that is not founded on a proper knowledge of the situation. I know, in my own experience, I have had rails reported to me as piped rails which were not piped at all. It is often reported that rails have failed from a pipe, when, as a matter of fact, the split head is the real cause of the failure. It is easy to tell the difference between a pipe and a split head if your men know what to report. Where rail is badly segregated and exceedingly hard in the center because the phosphorus and carbon segregate towards the center, it will often break down in the head, that is, the outside of the head will split away from the center. That rail is a dangerous rail compared with a piped rail or a rail which has a natural seam in the center due to the cavity in the top of the ingot.

We have discussed this matter, pro and con, in the Committee, and with others, and we do know that comparatively few accidents have occurred due to piped rails, so that the danger from piped rails is not so serious as one would think.

We think that most of the trouble attributed to piped rails is due to split-head rails, which is caused by bad segregation. Therefore the specification is gotten up with the idea of producing an ingot which will tend toward what is known as piping steel rather than segregated steel. We are not looking for piped steel, but we are trying to get away from the segregated steel, and we want to give the manufacturer an opportunity to do that. We do not know that we are going to get improved steel. Some are sure we will, and some are not so sure, but we feel it is only fair that we should test the specification out, and that is what we are going to ask the members of the Association to do.

What we want is a discussion on the floor of the subject, and we want the manufacturers to join in this discussion. We would like to get as much rail rolled during the coming year under the experimental specifications as possible, and also get it rolled as near as possible without changes. Of course it will be up to each railroad to fix this matter up with the manufacturer under special contract, but if we can get this test rail rolled at a sufficient number of plants we should be able to determine the value of the specification from a mill standpoint. Although the rails may show up well in the physical tests at the time of rolling, we are not sure what will happen in service, and we will not know for the next five years. This is one of the difficult problems of the Rail Committee. We are always dealing with unknown quantities and yet we have to rely upon the results of the past. When we go to the steel manufacturers and suggest a change, they naturally say—"We do not know what this is going to do." Neither does the Rail Committee or anybody else know surely what will happen until the rail is tried out in service. We think that the step we are now taking is in the right direction and give us a rail that will give us good service, and get us away from segregation, that we will have a more uniform steel and at the same time not require the manufacturer to add on an unreasonable price. The major part of the Rail Committee is very sure that we are starting on something that will give us a safe rail and at the same time not cost any more money.

The President:—Is there any discussion of this matter by members of the Association or manufacturers, or anyone else who desires to discuss this important matter of rail?

Mr. Gennett:—The inspection of rails indirectly committed to my charge constitutes such a large tonnage that, when so many interested ones are in convention, I feel obliged to report briefly on the general subject.

The year 1921 was not a particularly favorable one for rails. A splendid start was made in the first few months toward a large production, the principal mill rolling the enormous total of 92,000 tons in March and later making a twenty-four-hour record of 4,089 tons, but bad times soon overtook the mills so that the last six or seven months saw several of them nearly idle. Indisputably the best quality is produced when the mills are running constantly, for then the various steps of the process are in better harmony and the machinery and the workmen are keyed to the proper pitch. Intermittent mill operations bespeak unsatisfactory conditions in many directions, and from the standpoint of quality I am opposed to the two ten-hour turns or the two eight-hour turns as the basis for working time. For instance, when a mill is rolling on a short turn basis, and then perhaps only three or four days a week, it is not only difficult to maintain the proper spirit among the workmen, but the intervals between such shifts give too much opportunity for indifferent attention to the heating of the steel and for the influence of the cold machinery to manifest itself.

In 1921 the inspection of approximately 2,000,000 heavy section rails produced about 4.8 per cent of No. 2 rails and about 1.9 per cent of scrap rails, all so classified because of flaws, which figures are fairly representative of good practice. But frequent cases where the combined number of seconds and scrap run as high as from twenty to thirty per cent on individual heats indicate a variable quality of mill work, created no doubt to a large extent by the intermittent mill operations. One point that deserves study is the question of service obtained from rails of a heat on which the percentage of flaws actually found is excessively high.

Of the 2,000,000 rails mentioned approximately 40 per cent were made to some specification requiring a nick and break test from "A" or top rails and the classifying of such according to the appearance of the fracture. The number of "A" rails condemned because of showing interior defect on the fracture test amounted to 1.3 per cent of the total rolled under such specifications, but the number from one mill amounted to two-tenths of one per cent, while that from another mill amounted to four and two-tenths per cent. These figures emphasize again the wide difference that may be found in mill practice and one that is probably chiefly responsible for some rails showing so much better than others in service.

No important change in any customary mill practice has marked the past year, but of course the times have not been propitious for making either radical changes or improvements. It is important to note, however, that a new rail manufacturer has entered the field and the first rail rolled by the Inland Steel Company on March 9th places that mill among the contenders for future tonnage. Among the facilities for rail making that have been provided in that mill may be mentioned not only its ease of adaptation for delivering long rails, but arrangements for the disposition into other products, including tie plates, of what would ordinarily be the "A" or top rail metal.

This latter statement leads to the subject of specifications, and it is but reiteration of the well-known fact that, under present manufacturing conditions, one of two things appears to be an essential requirement of rail specifications, viz., either the nicking and breaking of a test piece from the top rail of each ingot, with the resultant classification of those rails based on the character of the fracture; or, and in lieu thereof, the discard of what would ordinarily be the "A" rail metal and its use in some other product, as, for example, tie plates. Experience has repeatedly demonstrated that the most constant cause of criticism is the incessant fault found with the action of "A" or top rails in track. It is plain that until the mills generally adopt some method of casting hot-top and big-end-up ingots, the liability of obtaining piped and segregated unhomogeneous steel in the top rails is so great as to require the adoption of more positive methods for combating the difficulties that follow the use in track of rails rolled from such material. Testing the top rail of each ingot is one method for protecting against the shipment of the inferior metal, and similar tests to those suggested were frequently made in this country, and with comparative ease, on war-time shell steel. But, in lieu of such testing methods, it has now been deemed practicable to provide for the disposition of the "A" rail metal by agreeing to its use in the form of hot-worked tie plates, and it is hoped that early in the future more mills may see clear to adapt themselves for such manufacture. On a recent order for some 45,000 tons of rail, coupled with 13,000 tons of tie plates, both the "A" and "B" rail metal could have been rolled into tie plates with obvious advantage. While it is true that the roads can effect some economy by the restricted use of "A" rails, still their opportunities to do so are limited and the total elimination of those rails is much desired.

It has been suggested that rail steel should contain a higher silicon content than has heretofore been common in this country, though some English rail steel has long been conspicuous for its high silicon. The English steel contains much less carbon than does ours, and the question of possible brittleness in the high carbon steel containing high silicon, and perhaps silica, is important for investigation. No doubt the more extensive use of silicon, if possible at the mills, will make the steel more homogeneous in some directions, but it is hazardous to expect it to so reduce segregation as to make that evil a matter of history, and the seriousness of the increased piping must not be underestimated.

On the matter of rail failures, it can only be said that after the troubles with "A" rails comes the constant and increasing menace caused by fissures, both transverse, horizontal and compound. No particular progress has been made in the last year toward locating and identifying the definite cause of fissures. I cannot help but feel, however, that as the cases multiply of fissures occurring on individual heats the rails of which are found distributed over considerable territory (as was once the case in four different states), and the history of those heats become known, that the burden of evidence points to some peculiar, but obviously unintentional, treatment that the steel has undergone as being the principal cause for the original nuclei. The steps being taken by the Rail Committee toward obtaining further data on this important subject should meet with the fullest of coöperation.

In conclusion, may I express the hope that future reports of failed rails issued by the Committee may be more extensive, rather than so abbreviated, and show, among other things, the success presumably being obtained with rails of the newer and heavier sections.

Mr. C. W. Baldridge (Santa Fe):—It happened to be my business at one time, for a period of about eight years, to study the rail in the track and the rail in scrap piles. One feature has come to my attention particularly, and that is that the rails rolled since about the beginning of 1909 cause more trouble from battered ends and flow of metal, particularly in the flow on the gage side of the rail, and the more or less projections that roll out on the outside of the rail, all of which is due to softer or more ductile rail. I have noticed that rails rolled prior to that time stand the wear better than the later rails.

In following up the history of the rail, and failures from transverse fissure, in the earlier cases, that is, the cases of transverse fissure in older rail, it was brought to my attention that the chemical requirements of the open-hearth rail, in the early days of making the open-hearth steel, was exactly the same as the chemical requirements of the Bessemer steel rails.

In studying the matter I discovered that the change in chemical requirements for open-hearth rail was adopted by this Association about

1908, as near as I can learn. I have not had time to search the records to verify this, however.

I have also been told by a metallurgist of the Colorado Fuel & Iron Company, from which we get considerable rail, that it was in 1908 that they changed the chemistry of the rail. Seemingly the open-hearth steel rails which we have been getting made under the chemical requirements that we are now working to, are not wearing as well as the rails rolled under the old specifications. In studying the metallurgy of steel I have learned this—the quotation is made in Stoughton's book on the "Metallurgy of Steel," in which he states, "by increasing the phosphorus an addition of 1,000 lb. per sq. in. is added to the strength of the steel for each one-hundredth per cent of phosphorus added, up to twelve-hundredths of one per cent."

Our old specifications permitted phosphorus up to 0.12 or 0.14 per cent. Our new open-hearth steel specifications require a phosphorus not to exceed .04, because it was assumed that phosphorus makes the steel more brittle. It does. If a sufficient amount of phosphorus has been added to the steel it will undoubtedly be too brittle for rail purposes, but 0.12 per cent is not sufficient to bring about such a result.

I believe we are getting more broken rails from our present type of steel, when we take into consideration the transverse fissure failures, the surface checks, detail fracture failures, and such others as occur in the way of straight breaks, than we ever got proportionately, size and weight of rail, under the older specifications, and I suggest that this Committee consider very carefully the matter of permitting a larger amount of phosphorus, thereby enabling us to reduce the present required amount of carbon in the rails. The content of carbon as required in the rails at present was adopted with the idea that a greater amount of carbon would offset the lack of hardness, due to the smaller amount of phosphorus, and it is my idea that the transverse fissure rail failures are due to some little circumstance which will sometimes happen at the furnace in the effort to get the large amount of carbon into the rail, which our requirements at the present time call for, and I believe a reduction of 10 or 12 points in the carbon and an increase of a few points in the phosphorus will tend toward making a more durable rail, and also aid in reducing the number of transverse fissure failures.

The President:—As I said before, the manufacturers present are welcome to say anything they desire. I am sure what they would say would be very valuable information to the members of the Association, who are interested in rails.

Mr. A. L. Davis (Illinois Central):—I would like to hear what Mr. Wickhorst has to say in regard to Mr. Baldridge's statement.

Mr. M. H. Wickhorst:—Phosphorus is a hardening element, but it also decreases the ductility at a very much faster rate than the carbon, so that it is much more desirable to obtain hardening by means of carbon rather than phosphorus.

What is perhaps the worst feature about phosphorus is that it segregates badly and is apt to form nodules of extremely hard material in the interior of the rail and such nodules, of course, are sources of interior weakness. It should therefore be the effort to keep the phosphorus down as low as possible and try to obtain the desired hardness by means of carbon.

Mr. H. M. Lull (Southern Pacific) :—I have noticed for several years the facts which Mr. Baldridge described, and it has occurred to me that there is one factor which produces these results other than the chemical composition of the rail, namely, change in the process of hardening which occurs in the track. In the last few years there has been a very great increase in axle load, and this seems to have a very serious effect upon what may be called a green rail. As soon as we lay the rail now we immediately run very heavy locomotives over it. There is no such thing as slowly case hardening the surface or head of the rail. It is immediately mashed, so to speak, whereas ten or fifteen years ago we had a rail of similar composition which received a slow hardening by a succession of lighter loads going over it, which had a tendency to gradually improve the condition of the head of the rail instead of immediately destroying the surface structure. It seems to me this must have some effect in causing the results which Mr. Baldridge has referred to.

Chairman Ray:—This experimental specification will be valuable for any of you wishing to get up a specification for your use.

I wish to again state that this is purely an experimental specification.

There is another subject which has been brought up for quite serious consideration in the Committee, and that is rail sections. The Association is on record as to rail sections up to 140 lb. per yd. I think it is in order at this time for the Chairman of the Sub-Committee on Rail Sections to present to you his own views as he has expressed them in a letter to the Committee, and I will ask Mr. Cushing to kindly do that.

Mr. W. C. Cushing (Pennsylvania) :—The reason for making this statement is that several of the very large railroad systems of the country have been considering the problem of increasing the weight of rail in use on these roads, and studying the design which should be used by them in making that change.

The Rail Committee is not ready to make any report on the subject, but I will make a personal statement here, which is not on behalf of the Rail Committee, but simply a statement of my own, explaining somewhat the situation from my own point of view.

Note on Rail Design

By W. C. Cushing

The crux in rail design is the width and depth of head necessary to perform its work with safety and economy.

That there are two general classes of the magnitude and character of this work was recognized by the Committee of the American Railway

Association, which fixed upon the acceptable designs of rail sections known as types "RA-A" and "RA-B."

The one set of conditions is heavy tonnage borne in territory of crooked alinement and steep grades, while the other set is centered in territory with better alinement and grade with the duty of carrying traffic of more moderate tonnage. Type "B" was intended to satisfy the former set of conditions, and type "A" the latter.

Having accomplished the reduction of many designs to these two general types, the problem of amalgamating them into a single type was passed on to the American Railway Engineering Association, and the Rail Committee after years of study succeeded in having a set of designs known as the "RE" rail sections accepted as recommended practice by the Association, the weights per yard of these several sections being 100, 110, 130 and 140 pounds.

Necessarily these new designs are a compromise design between the two "RA" types. Having arrived at an agreed-upon 100-pound section, the larger sections were for the most part expanded proportionately from it.

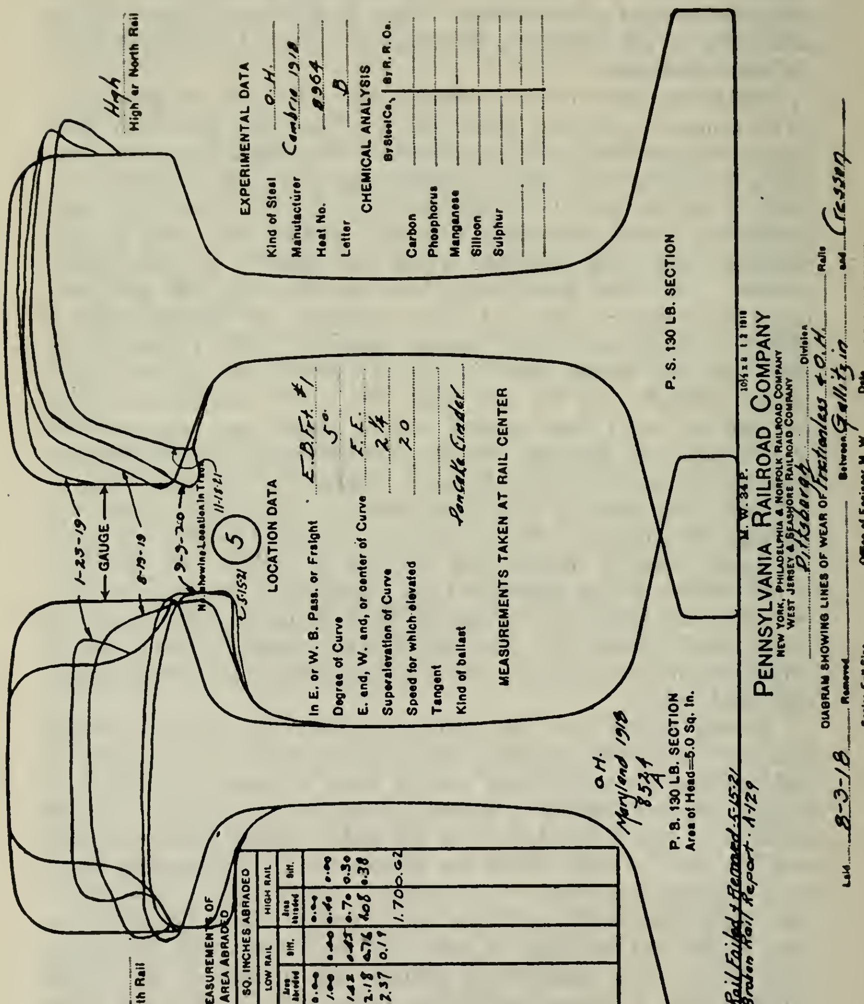
It has been deemed advisable to complete the series up to 150 pounds per yard and the Rail Committee has been studying such a design for several years, and as it is expanded from the other designs proportionately it has been recommended to the Rail Committee for presentation to the Association, but it has not been received by the Rail Committee for such recommendation. Nevertheless, I am presenting a copy of the design herewith, so that it may be recorded in the Proceedings for examination by the members, as it is based on the same principles as those already accepted. Then if any changes are made in the designs of the complete set, all of those making up the set can be dealt with at the same time. Some considertion has been given by a Sub-Committee to a revision of the present accepted designs, but it is evident at present that any change means a tendency towards one extreme or the other, and agreement on this point is not yet ripe for settlement. In fact, it is quite possible and even probable, that it will be desirable and economical to revert to two types in order to meet the two conditions outlined above, which are substantial facts.

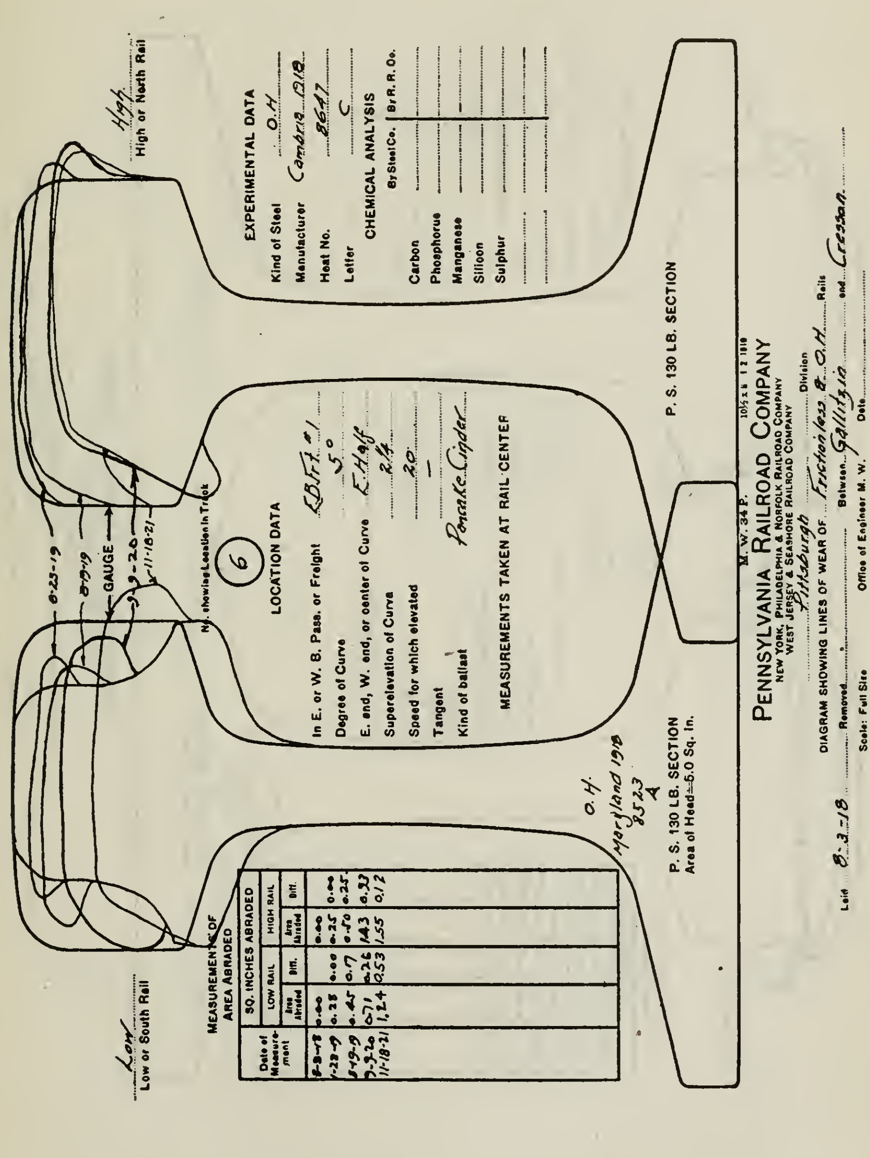
It has been proved many times that a heavy deep head is necessary for bearing safely and economically a heavy tonnage in territory of crooked alinement and steep grades, and as one illustration of this, the accompanying record of test of Frictionless and Open-Hearth Carbon Steel rails of the Pennsylvania Railroad between Gallitzin and Cresson are offered for instructive comparison. Many such examples can be given showing even greater wear in shorter time, as the test herein illustrated was made on a five degree curve, whereas many of the other curves are much sharper. This test was made on a Division carrying 7,412,862,252 gross tons of traffic in one year. The exact proportion which passed over the test rails cannot be given. It can well be understood from this and other trials conducted that no rail with thin head could bear up under this kind of service unless it should be of far superior strength and hardness so as to resist wasting away of the metal by abrasion of the wheels. There is no direct evidence of the superiority of the metal in a thin head over that of thick head under the same conditions.

Trials not only of this character, but also those bringing about direct comparison between heavy and thin head rails have been made on the Pennsylvania System, because the Pennsylvania System embraces railroads coming under both conditions of traffic and alinement outlined in the first place. In 1909 1,535 tons of "RA-A" rail were purchased for service comparison with the standard "PS" type of that Company, both being 100-pound weight and made by the same manufacturer. They were placed under both conditions of traffic and alinement: First—heavy traffic and sharp curvature, and Second—under a little less heavy traffic with tangent alinement. The results of the curve test have already been reported in careful detail in Proceedings of the A.R.E.A., Vol. 16, 1915, page 319, and it was shown in that test that the heavy head resisted abrasion longer, and was, therefore, more economical. Naturally, results from the test on tangent alinement could not be obtained so quickly, but the annual report of observation of rail tests, just received from that portion of the System, states that although the tonnage of "RA-A" type rail, purchased in 1909, was small, the results obtained indicate that this type of section with thin head is not adapted to high curvature track. Satisfactory results were, however, obtained by its test in tangent track at points not subjected to severe traffic conditions. The defects run largely to head failures originating in a breaking down of the head structure and terminating in split head rails.

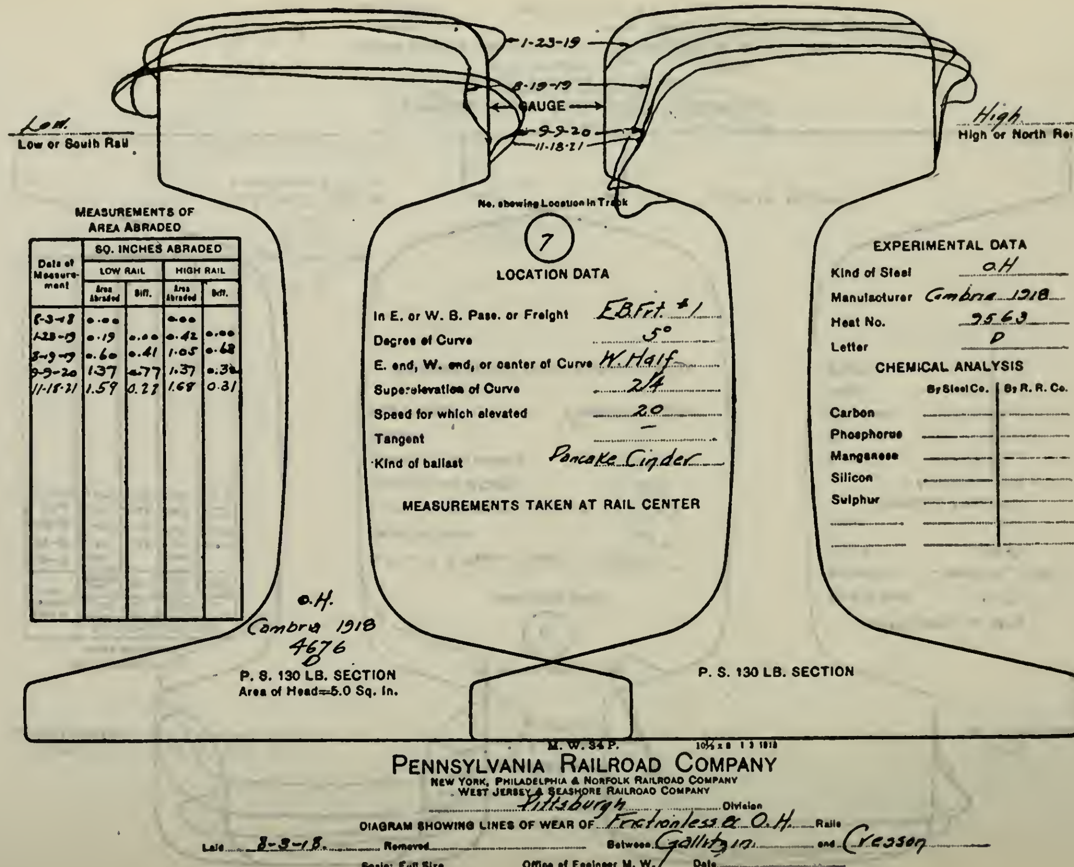
Having decided upon the quantity of metal for the head deemed essential for carrying the load bearing proper relation to wheel tread and allowing for considerable wasting away of metal before loss in strength requires removal, it is then necessary to decide upon a suitable thickness of base to avoid fractures and make a proper balance of metal with the head so as to render the problem of rail straightening easier by a minimum punishment of the metal. After that it is desirable to have the greatest height practicable with a proper relation between thickness of web and its height in order that the column shall be suitably proportioned, i. e., mathematical stiffness and strength of the section should follow the other requirements rather than be made the prime consideration.

It will be found that the practice of the companies with great density of traffic carried over crooked alinement and steep grades leans toward the rail design with heavy head and moderate height, being principally in the northeastern part of the country, while the western and southern companies of less dense traffic and larger percentage of tangent alinement

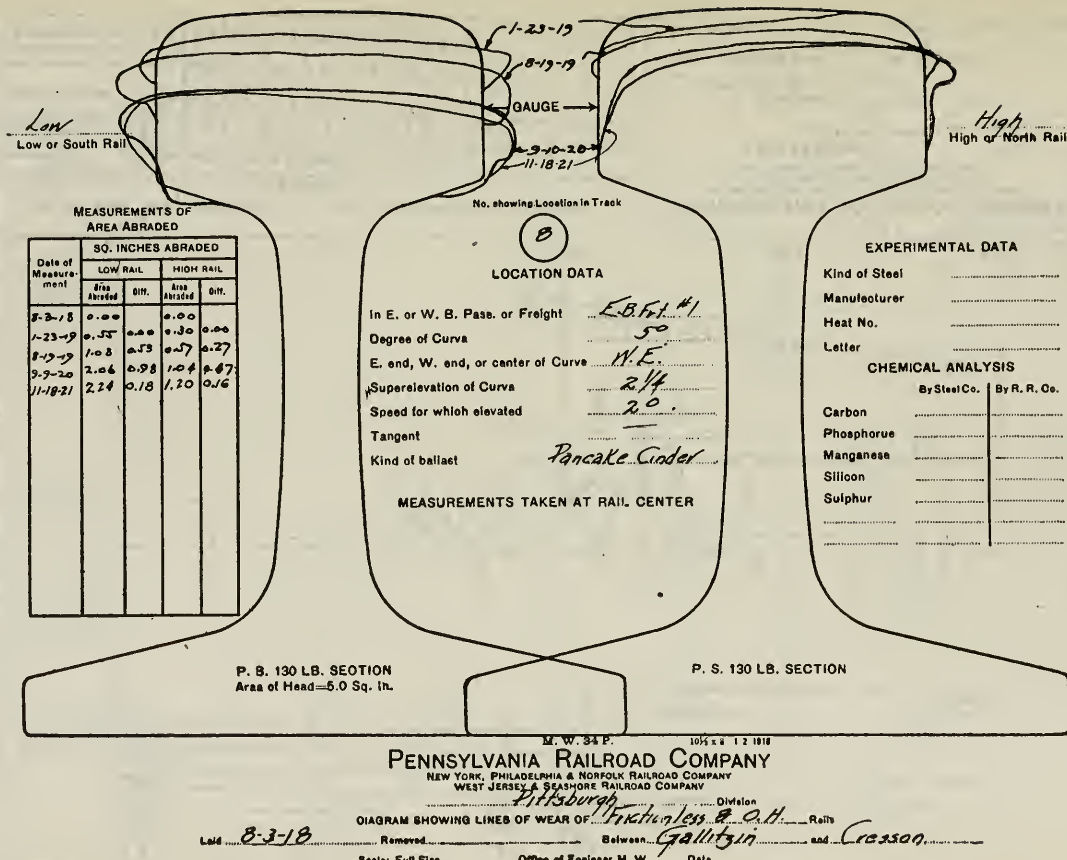

Low
Low or South Rail
High
High or North Rail
1-23-19
GAUGE
8-19-19
9-9-20
No. showing Location in Track
11-18-21
5-15-21
5
MEASUREMENTS OF AREA ABRADED
SQ. INCHES ABRADED
Date of Measurement
LOW RAIL
HIGH RAIL
Area Abraded
Diff.
8-3-18 0.00 0.00
1-23-19 1.00 0.00 0.40 0.00
8-19-19 1.42 0.42 0.70 0.30
9-9-20 2.18 0.76 1.08 0.38
5-15-21 2.37 0.19
11-18-21 1.70 0.62
LOCATION DATA
In E. or W. B. Pass. or Freight E.B.Frt. #1
Degree of Curve 5°
E. end, W. end, or center of Curve E.E.
Superelevation of Curve 2¼
Speed for which elevated 20
Tangent
Kind of ballast Pancake Cinder
MEASUREMENTS TAKEN AT RAIL CENTER
EXPERIMENTAL DATA
Kind of Steel O.H.
Manufacturer Cambria 1918
Heat No. 8964
Letter B
CHEMICAL ANALYSIS
By Steel Co. By R. R. Co.
Carbon
Phosphorus
Manganese
Silicon
Sulphur
O.H.
Maryland 1918
8524
A
P. S. 130 LB. SECTION
Area of Head=5.0 Sq. In.
P. S. 130 LB. SECTION
Note - Rail Failed + Removed 5-15-21
Broken Rail Report - A-129
M. W. 34 P.
PENNSYLVANIA RAILROAD COMPANY
NEW YORK, PHILADELPHIA & NORFOLK RAILROAD COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
Pittsburgh Division
DIAGRAM SHOWING LINES OF WEAR OF Frictionless + O.H. Rails
Laid 8-3-18 Removed Between Gallitzin and Cresson
Scale: Full Size Office of Engineer M. W. Date



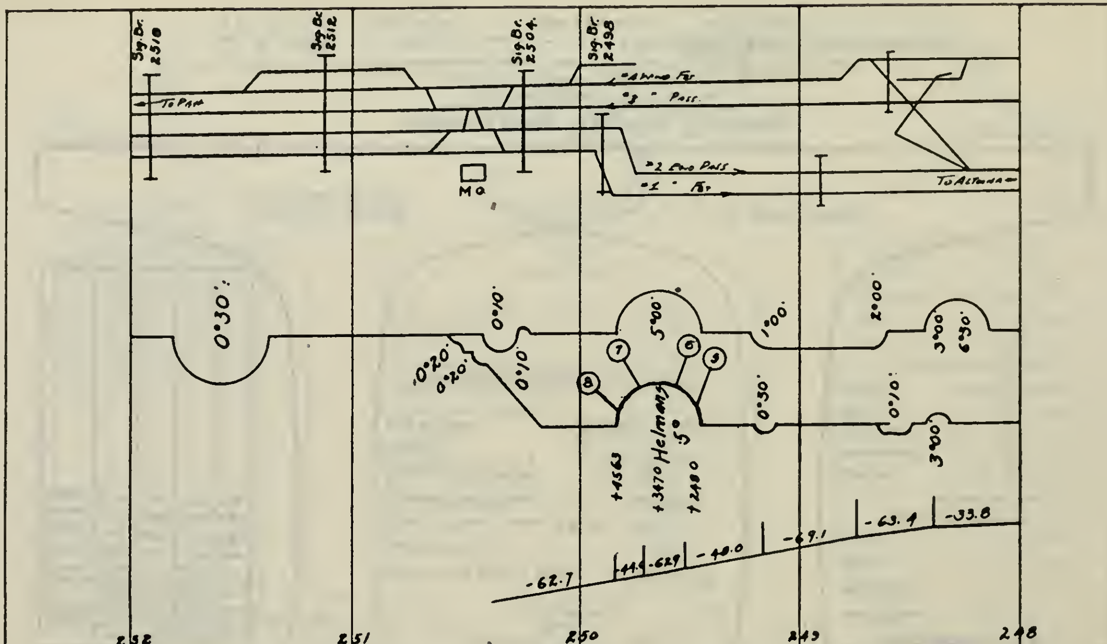
High
High or North Rail
Low
Low or South Rail
8-23-19
8-19-19
GAUGE
9-9-20
11-18-21
No. showing Location in Track
6
LOCATION DATA
In E. or W. B. Pass. or Freight
E.B.Frt. #1
Degree of Curve
5°
E. end, W. end, or center of Curve
E.Half
Superelevation of Curve
2¼
Speed for which elevated
20
Tangent
Kind of ballast
Pancake Cinder
MEASUREMENTS TAKEN AT RAIL CENTER
EXPERIMENTAL DATA
Kind of Steel
O.H.
Manufacturer
Cambria 1918
Heat No.
8647
Letter
C
CHEMICAL ANALYSIS
By Steel Co.
By R. R. Co.
Carbon
Phosphorus
Manganese
Silicon
Sulphur
P. S. 130 LB. SECTION
MEASUREMENTS OF AREA ABRADED
SQ. INCHES ABRADED
Date of Measurement
LOW RAIL
HIGH RAIL
Area Abraded
Diff.
8-3-18
0.00
0.00
0.00
0.00
1-23-19
0.28
0.00
0.25
0.25
8-19-19
0.45
0.17
0.50
0.25
9-9-20
0.71
0.26
1.43
0.93
11-18-21
1.24
0.53
1.55
0.12
O.H.
Maryland 1918
8523
A
P. S. 130 LB. SECTION
Area of Head=5.0 Sq. In.
M. W. 34 P.
PENNSYLVANIA RAILROAD COMPANY
NEW YORK, PHILADELPHIA & NORFOLK RAILROAD COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
Pittsburgh
Division
DIAGRAM SHOWING LINES OF WEAR OF
Frictionless & O.H.
Rails
Laid
8-3-18
Removed
Between
Gallitzin
and
Cresson
Scale: Full Size
Office of Engineer M. W.
Date



Date of Measurement	SQ. INCHES ABRADED			
	LOW RAIL		HIGH RAIL	
	Area Abraded	Diff.	Area Abraded	Diff.
8-3-18	0.00		0.00	
1-23-19	0.19	0.00	0.42	0.00
8-9-19	0.60	0.41	1.05	0.63
9-9-20	1.37	0.77	1.37	0.32
11-18-21	1.59	0.22	1.68	0.31



Date of Measurement	Sq. Inches Abraded: Low Rail, Area Abraded	Low Rail, Diff.	High Rail, Area Abraded	High Rail, Diff.
8-3-18	0.00		0.00	
1-23-19	0.55	0.00	0.30	0.00
8-19-19	1.08	0.53	0.57	0.27
9-9-20	2.06	0.98	1.04	0.47
11-18-21	2.24	0.18	1.20	0.16



A— OH. & OH. 130 shown in Red B— Frictionless & OH shown in Yellow

SUMMARY

Month and Year	Jan. 1919.		Aug. 1919		Sept. 1920		Nov. 1921					
Kind of Rail	A	B	A	B	A	B	A	B	A	B	A	B
Total sq. in. abraded	0.72	0.65	1.62	1.20	2.41	2.51	2.88	3.25				
Aver. sq. in. abraded per 3ec	0.36	0.33	0.81	0.60	1.21	1.26	1.44	1.62				
Area abraded, in percentage of original area of head	7.2	6.6	16.2	12.0	24.2	25.2	28.8	32.4				

M. W. 84 B J 10M 2 8 1 18 1919

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

PITTSBURGH Division

LOCATION DIAGRAM
OF

Frictionless & OH. Rails

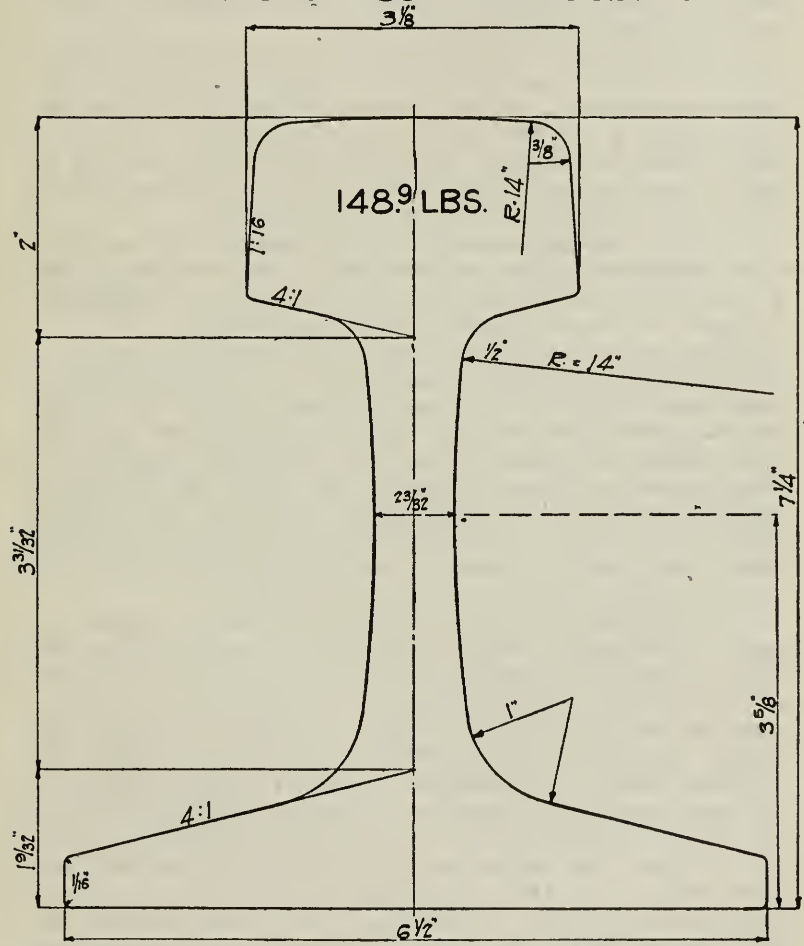
Laid 8-3-18 Removed

Between Gallitzin and Cresson

Office of Engineer M. W.

Scale: 2 in. = 1 m Date

PROPOSED 150 LBS. R. E. RAIL SECTION



Area: Head = 5.31	Sq. In.	36.5	
Web = 3.61	"	24.7	
Base = 5.68	"	38.8	
Total 14.60	"	100.0%	

Moment of Inertia	102.65
Section Modulus Head	25.80
Base	31.37
Ratio M. I. to Area	7.03
Ratio Sec. Mod to Area	1.77

with easy curves favor the thin head and great height of rail section. This is indicted in the tabular statement recently prepared by Mr. Hunter McDonald, Chief Engineer, Nashville, Chattanooga & St. Louis Railway, attached to his report of March 2d, to the Engineers of various railroads furnishing the information.

Of great assistance in the final solution of this problem would be the cost per mile per ten million tons of traffic borne by the different weights and sections of rail, but no reliable information of that kind has been furnished as yet. From careful observation, however, it has been estimated that the 130-pound rail on the Pennsylvania System in its heavy curvature districts outlasts by 2½ times the 100-pound section, and is worth 23 per cent more in reduced maintenance.

It has also been well-established that the failures of 130-pound rail on the Pennsylvania System are many times fewer than those of the 100-pound section, notwithstanding the fact that they are located where the traffic and alinement conditions are of the severest.

Having arrived at suitable size of head for meeting the conditions of traffic and alinement, stiffness, strength and lower unit stresses of the section must be sought for by increased weight per yard. At the same time advancement in that direction can be dealt with by improved quality of the material, meaning by that term homogeneity, toughness and density together with hardness consistent with them. Some preliminary information of the value of rail stiffness has been given in the preliminary reports of the Committee on Stresses in Track, indicating that increased stiffness brings with it a change in distribution of stresses which may interfere with the proportionate value of the increase.

I do not believe, therefore, that the time has come for making any change in the present adopted "RE" sections; especially as the 100-pound and 130-pound sections are now rolled, and if Mr. McDonald's recommendation to his managing officers is complied with, the 110-pound section will also be rolled. As a matter of fact there is extremely little difference between the 130-pound "RE" and "PS" sections. The "PS" section has slightly wider (principally by slope of the sides) and thicker (by greater slope angle under) head. It has the same design of base and slope except that the "PS" is ½ in. narrower (5½ in.) and "RE" 2/32 in. higher. The heaviest rail section used by any railroad is that of the Lehigh Valley, 136-pounds per yard. It has the same width and depth and the same slope for joint bearing both top and bottom as the "RE" 130-pound section. The Lehigh Valley design is 8/32 in. higher and has ½ in. wider base (6½ in.).

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I would like to bring to the attention of the Rail Committee with as much emphasis as I can the problem that a number of our roads have before them of recommending an increase in the section. I know that the tendency of most of the roads having dense and heavy traffic has been to make one big jump from a 100-lb. section or perhaps 105-lb. section to as high as 130 and 136. The Committee now has under consideration the designing of a 150-lb. section, as announced by the Chairman. I think the majority of our membership is much more interested in the establishment and stabilizing of the intermediate sections between 100 and 150 than they are in the completion of the 150-lb. section. I have discussed the matter to some extent with a number of Engineers here, and I find that their problems and the ones that I have been investigating are along the same lines. I have also had some discussion of the matter with the manufacturers who would probably undertake to roll the section I might recommend; but the question of whether when one goes from say a 90-lb. rail to a higher section he is likely to strike what will be the future standard or not, is a very important one, and it devolves upon the Engineer making this recommendation that he shall correctly forecast what the final adoption of the Committee is to be. I would like very much to emphasize the fact that effort should be made to stabilize this question as quickly as possible.

I would also like to ask the Committee if they will not revive that old question that was up a long time ago and that seems to have died a sort of a natural death, of using longer length rails than 33 feet. I think the matter which determined the present standard length of rail was largely that of transportation; the fact that rails must be transported in stock cars. I think there is no question but what a 66-ft. rail can be successfully used. I should very much like to see the Committee revive this question and endeavor to see what economies can be secured and what the prospects are of securing the privilege of having a 66-ft. rail rolled, if they find it advantageous to do so.

Chairman Ray:—The Sub-Committee on rail lengths has that matter under consideration, but it has not been very active this last year. However, it has not been lost sight of, and will be taken up this year.

Mr. J. L. Campbell (El Paso & Southwestern):—With some of the western roads the question of rail length is an active one and is receiving considerable attention, the proposal being to make the length 39 feet. This is an important question which should be actively considered by the Committee.

The President:—That concludes the report of the Committee, and the Committee is dismissed with the thanks of the Association.

DISCUSSION ON ECONOMICS OF RAILWAY OPERATION

(For Report, see pp. 727-774.)

Mr. L. S. Rose (Cleveland, Cincinnati, Chicago & St. Louis) :—The work of this Committee was divided up into sub-committees, and the chairmen of the various sub-committees will present the various portions of the report. Mr. Brooke, Chairman of the Sub-Committee on "Methods for increasing the traffic capacity of a railway," will present his report.

Mr. G. D. Brooke (Baltimore & Ohio) :—The report of Sub-Committee No. 2, on "Methods for increasing the traffic capacity of a railway," is found on page 729-745. You have doubtless read this report, but there are a few points to which I would like to call attention.

On page 729, near the bottom of the page, there is some discussion of traffic capacity and track capacity. As used in this report, the traffic capacity of a railway embraces the tonnage which can be moved over a given arrangement of tracks and the adjoining terminals, and it depends not only on the track capacity, but also on operating methods, ruling grades, size of motive power, equipment and capacity of the terminals. Theoretically track capacity is fixed by an arrangement of tracks and passing sidings which is theoretically perfect—that is, assuming that the sidings are so arranged that the running time of trains between them will be practically constant, so that the meeting points will be as near perfect as can be obtained—and this track capacity is measured in the train hours per day or per month or per any period of time, per mile of line or per division, or for any section of a line. The actual track capacity would be the actual train hours per day per mile, or per any given section of that line.

The Sub-Committee will doubtless in next year's report submit definitions for these terms so as to give a more clear understanding of the ideas, and to standardize the terms as far as practicable.

In the table on page 732 I desire to call attention to the fact that the highest ratio of actual track capacity to theoretical track capacity which the Committee has been able so far to develop has been about 25 per cent, and that the highest number of trains per day over a single track railroad for a period of a month is something a little below 30—27, 28, 29 trains per day.

There are doubltless engine districts, single track, in the country which are handling more traffic than that—considerably more, probably—but the railroads have not reported to the Committee if they received our questionnaire. It will very much assist in proceeding with the study if we can get information on those engine districts or portions of engine districts over which a very heavy traffic is or has been handled. To make the study we should have information similar to that given in items 12, 14 and 15 of the table on page 732, and should also have a print giving the track chart and profile, the track chart showing passing sidings and other features.

The diagram on page 735 shows curves indicating the tendency of the average train hours as affected by the increase in the number of trains, weather conditions and some other factors. The equation of this curve is developed on page 743. The Sub-Committee proposes to give this curve further study, to determine whether this is the correct curve, or whether under a very high increase of the number of trains the curve will flatten out at the top.

With a view of improving the diagram on page 741, and the tabular data on page 745, the Committee has arranged to have a paster or pasters provided as a substitute for the diagram, and for the tabular data, so as to put the information in better shape, and to make a working sheet of the diagram and table, so that this information can be more easily applied in studying actual traffic conditions.

I desire to express my appreciation of the able assistance of Mr. E. E. Kimball in developing this subject. He is the originator of this method of attacking this problem of operation, and has been very largely responsible for developing the subject to its present state. I would like to say that the Sub-Committee would be very glad indeed to have a full discussion of the subject. We are going ahead and trying to develop something that will be of value to railroad officers in designing improvements to railroads, and what we are looking for is information, and discussion of what has been done.

The President:—Is there any discussion on the report? I understand it is to be received as information. It is a splendid report and is something new. Probably there are operating men that would like to say something on that.

Mr. Hunter McDonald (Nashville, Chattanooga & St. Louis):—I noticed with some interest that portion of the Committee's report relating to the capacity of tracks. We happen to have on our line a section of about 45 miles which is principally mountain road, where we have to operate over a single track practically a minimum in normal times of 60 trains a day, and we sometimes go as high as 90. The success of that operation is brought about by coöperation among the operating men. I do not believe that any formula can ever be made to fit that condition. We realize that the section is very much congested, and the question of building a second track has been considered for a number of years. There are circumstances which prevent it being done. The cost is very heavy as compared with other means of increasing the capacity. The average speed of freight trains over that section is 8.8 miles per hour. A report has recently been presented to our management to the effect that by the installation of automatic signals and complete interlocking and dispensing absolutely with all train orders, directing the movement of trains entirely by signal indication, we would increase the capacity of the line about forty-eight per cent. The investment in that one instance represents about $725,000, most of which can be recovered when double tracking is resorted to, as against $2,200,000 for a second track alone. I will be very glad to furnish the Committee the details of the present operation of this section of single track should they desire it.

On the Nashville, Chattanooga & St. Louis Railway there was a section of six miles of track that was divided into three blocks and during the 24 years of its operation we moved as high as 168 trains per day over the single track and 220 trains over the double track portion. During the entire period there was only one collision due to the system, which resulted in nominal damage. This section of track was between Chattanooga and Wauhatchie, Tenn., around Lookout Mountain, and has since been double tracked.

Mr. Brooke:—The Committee will be indeed glad to get the information as to this piece of busy railroad. It will be most interesting, I think, for the Committee to follow the development of the traffic and to make use of that in developing our studies of the subject. It is the view of the Committee that use can best be made of this kind of study to enable railroad officers to determine upon what improvements to make under certain conditions. We want to try to develop logical methods of studying the subject, so that it can be determined with a reasonable degree of certainty as to whether what will be done is the best thing to be done, and to eliminate to the fullest degree any question of doubt.

Mr. C. E. Lindsay (New York Central):—One thing has come to my knowledge recently which shows how relatively small things influence track capacity. On our eastbound slow freight track east from Syracuse, which is thoroughly signaled with automatic signals, engines ordinarily haul 5500 tons. But about twenty miles east of the yard there is a water station, where there is a sag in the grade. The water station is located on the downhill side, so that the train gets a little start for the hill and then fifteen miles beyond that, over the top of the hill, is another water station. Ordinarily a train starts out and goes on signal indication and depends on signal indication to know what is ahead of it. The engineer knows, in his first block at least, what he has got. But the dispatcher now shares with the engineer a little of the responsibility of keeping that train going at a good rate of speed, so at the first station west of the first water station, if there is no train taking water at that station, the dispatcher instructs the operator to hang out a little white flag from the tower, and the engineer blows his whistle and he goes by that first water station and mounts the hill without a pusher, and goes to the second water station, which saves a great deal of time and increases thereby the capacity of that track wonderfully.

The President:—We will now pass to the next topic.

Mr. J. M. Brown (Chicago, Rock Island & Pacific):—When this subject of operating against the current of traffic was first considered by the Sub-Committee, it was found that information on the subject was very meager. The Committee therefore inquired of some forty-eight railroads what the practice was on those lines. These were roads with more than one track, and the purpose was to ascertain the operation in the regular order of business, that is, conducting actual operation against the current of traffic at any time of the day. Of the forty-eight roads requested to give the information, thirty-three replied; fourteen of those roads gave full information as to the extent the operation against current of traffic was indulged in by them. I do not know that I can add anything to what has been stated in the report as to the operation of each individual road. We regret that one road which does operate against the current of traffic to a great extent, the Pennsylvania, did not furnish us a report in time to be introduced into this report.

The Sub-Committee therefore offers the conclusion on page 761 for approval.

(Motion carried.)

Chairman Rose:—Professor C. C. Williams will make some remarks on the report of the Sub-Committee in Appendix B, page 746.

Professor C. C. Williams (University of Kansas):—The work of the Sub-Committee was divided into three sub-heads, the first being the effect of speed on the cost of maintenance of way; second, the effect of speed on the cost of transportation; third, the effect of speed on the cost of maintenance of equipment. Last year the Sub-Committee presented for information some studies on this first topic, but the Sub-Committee was unable to find verification of its results which seemed to justify final conclusions. However, the Committee saw fit to present as tentative conclusions the material given on page 746, which material is presented as information.

The Sub-Committee conducted a good deal of correspondence in an attempt to find operating results which would check or disprove these conclusions, but quantitative observations seemed not to be available. Operating men had impressions as to the effect of speed, but for the most part those impressions had never been reduced to quantitative statements. It is hoped, however, that in another year some further studies will add to this information.

One of the factors which so complicates observations on this subject, of course, is the effect of traction. It is so difficult to eliminate the effect of traction from the effect of speed in making observations that results have been obtained with a good deal of difficulty. This material is presented for information.

Mr. J. B. Jenkins (Baltimore & Ohio):—I understand that "C" is merely a co-efficient.

Professor Williams:—That is correct. It is the cost of that item on any particular road under any particular conditions.

Mr. Jenkins:—The report does not state what "C" means.

Professor Williams:—The fraction is the co-efficient, and "C" is the cost of operation.

Mr. Louis Yager (Northern Pacific):—The summary of the Sub-Committee's efforts on the subject of "Methods for Analyzing Costs" is found on page 748.

Subject No. 4 is a continuation of a previous assignment. This covers the development of methods for analyzing costs for investigation in which the Committee might be concerned.

We concluded that the activities of the Committee might be very much extended so that a method for analyzing freight train and passenger train mile costs could be developed and used as a basis for many economic operating comparisons. Considerable work has been done on this phase of the subject and the work is to be continued during the year.

The next assignment is No. 7, which is a new one. This assignment we take to mean the determination of the relation between the use of a facility, i. e., transportation units produced, and the physical reparation that should follow that use; as well as the determination of the maintenance increment that would follow an increase of that transportation machine. The work of the Sub-Committee for the past year has been devoted to a partial resumé of the work that has previously been done on this subject in various lines. We have reviewed and made a study of the various transportation units that have been used in previous investigations or suggested as worthy of further study. We have also given considerable thought to the other unit which belongs with this subject, and that is the unit or units of plant, the transportation machine, which should be related to the use unit after we develop it—these two units are being studied together.

We are collaborating with a similar Sub-Committee from the Committee on Records and Accounts. Considerable progress has been made, and we hope during the first few months of the study this year to develop some tentative conclusions for the preparation of a questionnaire to the membership of the Association, which we hope will give us useful information not now available in the study of the subject.

Chairman Rose:—In the Committee's report for recommendations for future work we ask to have subjects 2, 4, 5 and 7 reassigned. We would like to change that and have subject 3 also reassigned. We want to try again. I want to say for some of the questions that the Sub-Committees have reported on, Engineers who have had to do with the planning of improvements and justifying expenditures will get considerable help from the train-hour diagram as a means of comparison of the line at different times.

I do not know that we can do very much in comparing one railroad with another, but we can use this method for comparing before and after. We can also use it somewhat for predicting what we will get if we make certain changes.

The matter that the last speaker referred to was handled last year by the Board. I can understand why we have that subject.

The question whether you can spend too much or too little on the maintenance of track is a very vital one nowadays. In order to make yearly or monthly allowances for maintenance of any work, an effort must be made to determine what is the right amount, and Engineers interested in that question should help the Sub-Committee with their work on that line, as it will help us and those having to do with appropriations for maintenance work.

Mr. R. H. Ford (Rock Island) :—I am glad that the Committee feels that they want to give this matter further study and trust that they will have the support of the membership during the coming year to permit a worth-while report to be made this year.

Mr. C. A. Morse (Chicago, Rock Island & Pacific) :—I am very much interested in what this Committee has done. I have had occasion to try to justify the installing of double track many times during the past twenty years, and every time I went into the literature to find out what had been said on the subject I found that everybody was steering clear of it. The Committee has it in hand, and I hope they will keep at it.

Outside of our double-track line on the Illinois Division, the heaviest traffic we have on the Rock Island Lines is between Kansas City and Herington, a distance of 140 miles, the first 66 miles of which is double tracked.

In 1915 I had some figures made as to the speed per hour of trains on the first 98 miles between these points. On the first 66 miles (double track) we were making at that time 16.1 miles per hour on drag freight trains, and on the next 32 miles (single track) we were making 7.5 miles per hour. We built an extension of six miles of second track at one end of the 32-mile stretch and four miles of second track with a terminal at the other end. The figures that we have on the building of this ten miles of second track show that the speed of the drag freight trains on the 32 miles has increased from 7.5 miles per hour in 1915 to 11.1 miles per hour at the present time, so that to-day with 22 miles of single track in the gap, four miles of second track at one end and six miles at the other, we are making 11.1 miles per hour over the 32 miles as against 16.3 miles per hour over the 66 miles of double track. Therefore, we have the difference between 11.1 miles per hour and 16.3 miles per hour as the additional speed we shall get for our drag trains by closing this gap with a second track.

There is a difference of half a mile in the distance between Kansas City and Fort Worth over our line and over the line of one of our competitors; we are each trying to make a record in securing business, and every additional mile of double track that we get helps out in the competition.

Just these things that the Committee has taken up are of vital importance in increasing the capacity of the road. My argument is that the roads having the most second track have a decided advantage and will earn the most money.

The President:—Did you only consider the speed per hour and not the tonnage per hour?

Mr. Morse:—We were drawing the same tonnage, the same trains.

The President:—The Committee is dismissed with the thanks of the Association.

DISCUSSION ON WOODEN BRIDGES AND TRESTLES

(For Report, see pp. 706-726.)

Mr. W. H. Hoyt (Duluth, Missabe & Northern):—The Committee on Wooden Bridges and Trestles had for consideration this year three main subjects. The first is Revision of the Manual. This work has been in the hands of the Sub-Committee, of which Mr. Ridgway is Chairman, and I will ask him to present the recommendations of the Committee on that subject.

Mr. A. O. Ridgway (Denver & Rio Grande):—For a good many years this Committee has been hoping to see some substantial changes adopted in the arrangement of the Manual. We have been told that it was not possible to effect that just now, so we have been confining our work to such changes of definitions as come to our notice.

I move the adoption of these changes and the addition of one definition to the Manual.

(Motion carried.)

Chairman Hoyt:—The second subject assigned to the Committee is "Wooden Trestles—open deck, multiple-story and ballast deck." The Committee has spent a good deal of time on this part of our report. Last year we submitted a progress report. and supplied information based on the results of questionnaires which the Committee sent out. We also received some discussion and communications which were of interest, and the Committee this year have brought together that information and now submit it to you for your consideration. Mr. Van Auken, the Chairman of the Sub-Committee, has been called away, and I will therefore submit the report for him. It appears on pages 709-13. Your Committee has submitted a boiled-down synopsis showing the basis on which its recommendations are made. The recommendations are shown on page 714 and subsequent pages.

I would move that the plans for standard open-deck trestles, light design, and also heavy design; standard open-deck frame trestles, light design and heavy design, shown on pages 714-17, inclusive, be approved and published in the Manual.

The President:—This is a splendid report, and if there is anything to be said or changes to be made, we should hear them now. The report shows a great deal of study and work.

Mr. A. F. Robinson (Santa Fe):—This set of plans for timber bridges is one that requires an immense amount of study and labor. It is essential that we provide for the unit stresses and the impact. The present set of plans has dodged the impact question entirely. In my opinion this report is all right if it is submitted as a progress report and not submitted for publication in the Manual. I do not care how good a set of plans is, we should not approve them unless they cover the entire proposition. When they go into the Manual, they are there to stay for some time.

The Committee has submitted three panel lengths for their bridge, and two depths of stringers. They have also gone quite largely from the two-panel length basis to the one-panel length basis.

There are features in these plans that I do not think any of us would want to accept in the way that they are given. In the first place, as to the details of the plans. The scales are altogether too small, and the letters and figures too small in the original drawings to permit their proper showing on these small sheets, but that can be overcome. There are some features that are admirable, others not so good. For example, the plans do not give any working dimensions. They say a 12 by 14-inch cap, a 7 by 16-in. stringer, and all these must have working depths, every one of them, especially where you are using creosoted material. Another item on the sheet shows that the frame bents are on concrete. They are only frames in name. They have the braces at the bottom, but if you are to have a bent that will do service it is best to have one with a cap and a sill.

I do not think the longitudinal bracing has been carefully studied out. In the bracing shown here you have holes, and in a little while the bolts bend or the holes in the bracing (3 by 10 in.) wear longer. We should have a longitudinal brace that braces. This bracing is not effectual, and costs more than a stiff rigid system of bracing.

To go to the ballast deck, you will find 8 by 8 ballast guards with vertical bolts down through them. You will not be able to hold these in that position without "S" straps. These steel bars or straps go from the top of the guard timber down at a proper angle to the surface of the floor timber, and the guard rail bolts or holding bolts go through the "S" strap, through the stringer, and at the other end they are held with a lag screw.

It would be interesting, perhaps, to know something about how the unit stresses in the stringers run. I note that they show 7 in. by 16 in. stringers and 9 in. by 18 in. The plans also show 12 by 14 in. caps, and also 14 by 14. They ought to be made one or the other.

In running over hurriedly the 12-foot panels, the light design, I find if we allow the impact conditions that are required by our steel bridge specifications under the E-60 loading, the fiber stresses show 3,290 lb. per sq. in.; under the E-40 2,440 lb. per sq. in. In the 16 ft. panel, light design, the fiber stresses in the stringers E-60 are 3,520 lb. per sq. in., for the E-40, 1,445 lb. per sq. in., and with the heavy design for the 12-foot panels, E-60 loading, with its impact, gives 2,465 lb. per sq. in. fiber stress, and in the 16-ft. span 2,657 lb. per sq. in. In the ballast deck with the regular allowance for impact the fiber stresses shown are 2,480 lb. per sq. in.

I do not think it is wise for the Association to multiply sizes of stringers and panel lengths. I see no reason why we should not adopt one size of stringer with uniformity in the size of the cap, and a uniform panel length, whether for light lines or heavy lines.

Another feature is that we are figuring now on the E-60 loading, but we are going to get heavier loading and we must provide in advance for further increases.

These plans are very good as far as they have gone, in certain sizes, but I believe the Committee should adhere to one panel length, be it long or short, and one size of stringer, and one size of cap. Let us see if we cannot simplify matters. It would be too bad to have these plans put in the Manual and find that about the time we got them there no one wanted them. Let us hold off for another year, until the Committee can get the question of impact and unit stresses in line and have their plans thoroughly and properly worked out. I do not believe any of you would accept the plans presented for drafting room work.

I hope the Committee will change their recommendation and submit the plans as a progress report.

Chairman Hoyt:—Mr. Robinson has referred to several items that will come up later. We are only submitting now the four standards for light and heavy pile and frame trestles.

The Committee did not ignore the question of impact by any means. It was thoroughly and carefully considered, but in submitting the plans the Committee did so on the basis that the design was amply strong to take care of the strains within reasonable limits, as they would be applied. We did not propose to run an E-60 over the light form of trestle. In designing these structures it was thought best to base our plan upon the E-60 or heavy loading, and the light loading to run down to an E-45 or not less than three-quarters of E-60.

In going over the E-60 it was assumed—and I think rightly—that most roads will give consideration to steel or concrete structures.

On the matter of simplifying the number of spans, last year our tentative report and discussion upon this matter asked for information on that particular point. We have received a number of communications from various railroads, but it was impossible for us to submit a single plan that would fit in any way all conditions. It also seemed impossible to submit a standard trestle with a standard stringer, or a standard cap that would fit all conditions.

The Committee itself is not agreed upon these particular details; but we feel that the individual Engineers will undoubtedly fit these plans to the particular conditions for which they are designed, and it is the aim of this Committee to submit something toward which the designs can be brought, in order to bring about more or less standardization and provide a larger market for standard sized timbers.

In regard to Mr. Robinson's criticism as to the type of drawings presented, it is true that the letters and figures are more or less reduced in size and difficult to read. That, of course, can be remedied. Any Engineer's office would, of course, draw their own designs and not attempt to use this particular type of drawing.

I desire to have it understood that my remarks apply to these four particular designs.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis) :—Mr. Robinson knows what he is talking about. Some thirty years ago Mr. Robinson gave me the first instruction I received in bridge engineering at St. Paul on the Burlington Road. He at that time had prepared for use of that road a set of standard plans for pile and frame trestles which I think were the best ever produced. They were far in advance of the common practice at that time. They carried details that have survived to this day. I feel that the remarks he has made in criticism of this report should be given great weight.

Mr. Robinson :—As these plans are designed they will oblige us to use fir timber almost entirely for our stringers. When you get to the 9 in. by 18 in., it is practically impossible to obtain Southern pine that is more than 16 in. in depth for stringers. We should not make our design so that it will rule out all the territory that is supplied with stringers from the South.

Mr. E. A. Frink (Seaboard Air Line) :—I agree with what Mr. Robinson says about the bracing of these trestles. The bracing as shown on some of these sheets seems to follow the steel practice, whereby each pair of bents and its adjacent span are treated as a unit. You cannot treat a wooden trestle that way, but must treat the trestle as a whole and have the bracing put in as a whole.

I am not in accord with Mr. Robinson's remarks about the stresses, size of timber, etc. The practice in steel design we are familiar with. We know the unit of impact allowance and how to use it. It seems to me the steel designers have to some extent lost sight of the fact that altered material and altered conditions should vary the amount of impact. It is perfectly proper to design a wooden trestle along theoretical conditions, if the assumptions on which you base your formula are correct; but if you do not have the right assumption, necessarily the results must be wrong. I do not see how it is possible to get the same impact effect on a wooden trestle that you get on an open-deck steel bridge. The stringers themselves are yielding and elastic, the bents are yielding and elastic, and even the supports are yielding and elastic, and these things modify the impact, and I think it would be wrong to design a wooden trestle with the same impact allowance as you design a steel bridge.

I would go further than Mr. Robinson in regard to the size of the stringers, instead of saying that the stringer should not be over 16 in., I would say that 14 in. would be sufficient. We must not make the mistake of placing too great importance on theoretical design in a matter where some of the assumptions are somewhat doubtful. It is better, in a case of that kind, to depend a good deal on practice. There are examples all over the country of 7 in. by 14 in. stringers on a 12-ft. panel carrying loads from 50,000 to 60,000 lb. on an axle and carrying it day after day. That is a fact. It may not be according to the theory as we write it, but when it is not according to the theory as we write it, I begin to suspect some of the assumptions for our theory are wrong.

We will find cases where a timber trestle of a certain dimension has carried the load for a number of years, and we can assume the trestle is safe for the load. Because we find some trestles of heavier make carrying the same load, we should not disregard the fact that the light trestle is also carrying the load. The trestles of heavy makeup are not positive evidence, they are negative evidence, that they will carry the load, and the light ones are positive evidence that the trestle will carry the load.

I am not in accord with Mr. Robinson as to the matter of the cap. For one size cap the yellow pine timber will suffice, but in other cases other timbers of large dimensions will be necessary.

Mr. W. H. Courtenay (Louisville & Nashville):—I agree with Mr. Robinson, particularly as to the impracticability of getting 18-in. stringers from longleaf yellow pine in the South. The time has passed when that size timber can be had.

I do not agree with Mr. Frink on the 14-in. depth of stringer. A very important consideration in trestles is to have the stringers reasonably stiff. For that reason I think we should hold to the 16-in. depth of stringer as long as it can be had.

One very important consideration in regard to the bents, particularly when creosoted piles are used, is to have the caps wide enough to cover the tops of the piles. If the tops of the piles are not covered, they will rot out much faster than if they are covered by the caps.

As to the use of stringers, and more of them, it is practically impossible to get an equal distribution of the loads on four stringers—the stringers under the rails must deflect to distribute load to the others, and it is important to reduce the deflection as much as practicable. There is too much deflection in stringers of trestles now.

There are many difficulties confronting us in the design of trestles—difficulty of getting equal distribution of loads and on the material. As to longitudinal bracing of trestles, making the bracing continuous, as suggested by Mr. Frink, I am opposed to that. The company I represent has about sixty-six miles of trestles, and we find that the bracing of trestles in two bent towers is successful. We have built wooden trestles from 125 feet high down to three feet high. It has been our practice for many years to keep a record of suggestions from our bridge supervisors, when they have suggestions to make, based on their actual experience, and the present plans have been evolved from a careful consideration of suggestions received from time to time, for trestle drawings have been changed frequently, and we do not hesitate to change the form of construction when there is a reason to change it, and that is one of my objections to standardization. I think the day will come when the difficulty of getting suitable timber will compel us to adopt other construction than wooden trestles. We can get yellow pine in the sizes desired now, but it cannot be had at the same price nor of the same quality as years ago.

Mr. Robinson:—I have no desire or intent to say anything about impacts. I simply know if we use the impact formula of the steel bridge specifications, certain results follow, and we should have that question settled for our timber bridges. If it is necessary to have a different percentage of impact, let us have it.

Regarding the caps, the piles we obtain run from 14 to 18 and 20 in. in diameter, and a 14-in. cap is no better than a 12 in., as far as covering the head of the pile is concerned.

No provision is made in the plans for blocking or furring pieces which should be tacked onto the side of the cap where the upper end of the sway brace comes on in order to prevent the men from adzing off the side of the pile to get the sway braces straight.

Mr. Courtenay:—I cannot agree with Mr. Robinson about the caps, with respect to the size of the pile, for this reason: There are on the Louisville & Nashville piles that have been in forty-five years. The caps originally placed on these piles were probably about 16 in. wide and still it is true that some of the tops of the piles are sap rotten now. They are not heart rotten. It is difficult, on account of its cost, to keep a cap wide enough to cover the head of every pile, and in our case we trim down the head of the pile in each case, fitting the cap to the head of the pile, and then covering it with hot creosote oil and pitch.

As to the effect of impact on timber trestles, I agree with Mr. Robinson it would be desirable to have it determined. I do not think the effect of impact on timber is the same as on steel.

Chairman Hoyt:—This discussion between Mr. Robinson and Mr. Frink and Mr. Courtenay simply illustrates the difficulties of the Committee in correlating 72 different combinations of stringers, braces and spans into four proposed standards towards which we might eventually, perhaps, draw our designs. The disagreement does not seem to be so much in regard to the work of this Committee as to the difference between their several ideas as to what a design of trestle should be, and if we have further discussion it will develop that each and all of us who are concerned in this matter will have our individual ideas as to what these designs should be.

The Committee had under its consideration the size of stringers and the span. There are roads using 10-ft. spans successfully, and roads using a maximum of 16 ft. Some use Southern yellow pine and others use fir. Last year the Committee brought in a tentative recommendation for a 12-ft. span. Since that was brought out, we have had quite a number who have indicated that they would not find it easy to go to the 12-ft. span. The Committee took it under careful consideration this year and decided there was no serious objection to introducing in the report a 16-ft. span. These provide for two different districts, a 12-ft. and 16-ft. There are some districts were the timber runs not over 16 in. deep without extraordinary cost, and in some cases it has been cut to 14 in.

On the question of depth, out of 114 roads making returns there are 87 using a 16-in. depth, and they are using 7, 8, 9, 10, 12, and 14 in.

widths. The depth is one of the important dimensions of the stringer. Others use 18 in. depth, but the predominating size is 16 in. Some of the roads with large mileage can easily get 18 in., and some even use 20-in. timber, and the reports are that there is no difficulty in getting 18 in. timber for that purpose.

As to loading, there are still a large number of roads in the country using less than E-50 on their engines, and for those roads we did not feel like limiting them to the heavy standard E-60. Therefore we have brought in the design for the E-45 load. That brings about the four designs, which I do not think we can get away from and satisfy all the districts represented in this country by 128 plans.

As to the size of caps, the predominating sizes were tabulated, and among the replies we received there were only 19 out of 103 who use the 14 by 14, and 60 use the 12 by 14, and the balance 12 by 12. The predominating size is 12 by 14, and they use them not on the lighter loads alone, but on the heavier loads, and we think it would be well to have the 14 by 14 as the standard for the heavier loading trestles.

On the frame bents, 30 use the 12 by 14, 23 the 12 by 12, and 4 the 14 by 14. Here it appears that 12 by 14 was the predominating size, and we chose that size for the lighter loading trestles.

Mr. W. E. Hawley (Duluth, Missabe & Northern):—This Sub-Committee sent out during the year a questionnaire in reply to which they received 128 designs. These designs covered both pile and frame trestles, and also ballast deck practice, as far as it had been used by the railroads. They have tabulated that data in a very careful way and they concluded to submit these designs with due reference to the tensile strength, sheer stresses and compression on the caps.

On the question of impact, which Mr. Robinson brought up in the first part of his discussion, the figures which he quoted ran to 3,200 lb. and 3,400 lb. per sq. in., and it seemed like a severe test on the strength of the trestle, but we are working in accordance with the tensile strength and fiber stresses allowed in the tables which were promulgated by this Association in 1909 and put in the Manual in the form as we have them in 1915. These tables specifically state that impact would not be allowed in using these values. This explains why the introduction of that information, Mr. Robinson's figures of 3,400, seemed so very startling. If you have impact you will get such figures, but if you will follow the practice of the Association in timber structures and ignore the impact in unit stresses, you will get figures nearer 1,400 or 1,500 lb. per sq. in., which is good practice.

In our questionnaire sent out to the various roads on the subject of whether they allow impact in figuring the stresses of their trestles, we had some 61 answers. Fifty-five reported no, and only six added impact. We also took up with the Forest Products Laboratory at Madison a discussion of this feature, and they came back with the explanation that timber where it is suddenly loaded and released, is not subject to the same structural effect as where it has a long continuous loading, and that is the explanation why we can take advantage of the timber and ignore the impact.

Mr. C. F. Loweth (Chicago, Milwaukee & St. Paul) :—I have been interested in the statement read showing the relative practice by the different roads from which the Committee received replies. Can the Chairman advise what proportion of the roads replying were using five piles in each bent for the heaviest class of structures, and what part were using six piles?

Chairman Hoyt :—Answering Mr. Loweth's question, of the thirty-three designs for heavy loading trestles submitted in reply to the Committee's questionnaire, we received the following information: Four piles per bent were indicated in nine designs; five in twelve designs; six in eleven designs, and seven in one design.

Mr. Robinson :—I move as an amendment that the plans be received as information and referred to the Committee for further study.

Mr. L. J. F. Hughes (Chicago, Rock Island & Pacific) :—In support of the amendment, I wish to call attention to the fact that on these plans a fundamental dimension was left out, namely, the distance from base of rail to cutoff. This is a dimension which must be measured in the field and certainly ought to be shown on these plans which are to go into our Manual of standards. I note on one of the plans this dimension has been given, the one in Exhibit 4, and has been left off of the other three.

Mr. E. M. Grime (Northern Pacific) :—On page 711, Bulletin 243, the Committee recommends that drift bolts be used to fasten stringers to caps, the chief reason being that this method is used almost twice as often as all others.

In my opinion it is a mistake to fasten stringers in this manner. In a wooden bridge the end of the stringer is one of the first points to show signs of failure and a vertical hole through the stringer weakens it, permits the entrance of moisture and thereby hastens decay. Also the cap is weakened by the hole in it directly at the bearing point and a connection of this kind tends to split the cap or at least to open up a crack.

Even though this method may be in quite extensive use, I think it would be a mistake for the Association to recommend it as standard practice.

On page 720, Exhibit 7, the Committee shows a method for fastening stringers to caps by means of an angle iron and bolts. This represents good practice and I would therefore recommend that the method of fastening stringers as shown in Exhibits 1, 2, 3 and 4, pages 714, 715, 716 and 717, be modified to conform with the method shown in Exhibit 7, which apparently the Committee does not favor.

I would also like to see the plans modified to indicate the use of bolts for fastening ties to stringers instead of drift bolts, which are liable to crack the timber and at best are but a crude fastening. Bolts are much more effective and slight additional expense should not be considered.

(The amendment was put to vote and carried.)

Chairman Hoyt:—I move that the report of the Committee as shown on page 718 for multiple-story trestles, Appendix B, Exhibit 5, be approved and printed in the Manual.

(Motion carried.)

Chairman Hoyt:—I move that the recommendation of the Committee for ballast deck trestles as shown on page 719 and the lower half of page 721, Appendix B, Exhibit 6, be approved and printed in the Manual.

(Motion carried.)

Your Committee submits for information the report of its Sub-Committee upon recommendations for fireproofing wooden bridges and trestles, and it will be explained in a few words by Mr. Heritage, the Chairman of the Sub-Committee, who prepared it.

Mr. C. S. Heritage (Kansas City Southern):—This report on the best method of fireproofing wooden bridges and trestles was prepared after a considerable amount of study and investigation on the subject. Of course wood is an inflammable material and it is impracticable to make a wooden bridge absolutely fireproof, so the report is really more of a fire prevention nature than fireproofing.

(Reading recommendations on fireproofing on pages 724-5.)

Chairman Hoyt:—I move that the recommendations of this Committee in regard to fireproofing, as read by Mr. Heritage, and printed on the bottom of page 724 and the top of page 725 be approved and printed in the Manual.

Mr. Grime:—The ballast deck bridge has been in use but a few years on most railroads. Considering the fact that its initial cost is greater than the standard pile bridge and the maintenance of it more difficult and expensive, it is not likely to come into very general use.

Galvanized sheet iron covering on stringers and caps is very effective fire protection for the deck of a wooden bridge and I would therefore suggest that the first recommendation under the head of fireproofing at the top of page 725 be modified to avoid reference to ballast deck trestles and to read as follows: "The decks of wooden bridges shall be protected from fires starting from hot coals dropped from locomotives, preferably by covering the stringers and caps with rust resisting sheet metal."

(Motion carried.)

Your Committee also presents for information the part of Appendix B, appearing at page 720, which is simply detail of design, as information, and will make no statement in regard to this except, of course, it is understood that it will go in the Proceedings.

Exhibit 8 gives a synopsis of information received by the Committee in its study of wooden bridges and trestles.

We now have recommendations in regard to the future work of the Committee, and they are printed on page 707. In addition to the four recommendations submitted, there is one in addition that has come up since coming to this meeting that I would like to submit to the Board of Direction for its consideration when allotting work for next year, it is as follows: "To report upon the classification of the uses of timber and lumber under the A.R.E.A. specifications." In regard to that recommendation I want to say that this came to us from the American Railway Association, and their Committee on Purchase of Lumber and Timber desires us to make a further report in detail of these specifications and classifications for their benefit. It is very important, and the Committee would be very glad to go more into detail, and to prepare such a report if the Board of Direction sees proper to consider it. I think that completes the work of the Committee.

The President:—The Committee is relieved with our thanks for its valuable report.

DISCUSSION ON BUILDINGS

(For Report, see pp. 775-897.)

Mr. W. T. Dorrance (New York, New Haven & Hartford):—The Committee has made a complete rearrangement of the subject-matter now in the Manual with a view of having it in such shape as to be more readily usable and easier to look up the various subjects covered. The Committee at this time has no recommendations to make as to any changes in the subject-matter of the Manual.

Regarding Subject No. 2, Specifications for Buildings for Railway Purposes, at last year's convention the Committee submitted specifications for eight subjects with the idea that the specifications be of loose-leaf form so that any combination necessary for any particular building could be readily assembled. Unfortunately Mr. Orrock, of the Canadian Pacific, Chairman of the Sub-Committee handling continuation of this work, is not here today. This Sub-Committee has during the past year continued the work of preparation of specifications and has completed specifications for seven additional subjects. These are given in Appendix A of our report, page 777, of Bulletin 245. The subjects covered this year are Painting and Glazing, Plumbing, Heating, Stone Masonry and Cut Stone Work, Clay Hollow Tile, Steel and Iron Work, Marble and Tile Work. The Committee offers these specifications for discussion, but does not suggest their formal adoption at the present time. This makes the specifications presented for discussion as follows:

1. General Conditions.
2. Excavation, Filling and Back-filling.
3. Sewers and Drainage.
4. Concrete.
5. Brickwork.
6. Carpentry and Mill Work.
7. Lathing and Plastering.
8. Hardware.
9. Pointing and Glazing.
10. Plumbing.
11. Heating.
12. Stone Masonry and Cut Stone Work.
13. Clay Hollow Tile.
14. Steel and Iron Work.
15. Marble and Tile Work.

The Committee had hoped that there would be a considerable amount of criticism on the specifications presented, and were much helped by the criticism that was received. Unfortunately we did not get a great deal of this and desire very strongly this year to have more assistance from the Association at large so that we may know whether any changes should be made in the specifications before they are offered for formal approval. We believe that they are now in such shape that they might be helpful and that perhaps some use might be made of them at the present time, and we would welcome any indication of such use.

There are one or two subjects that have not yet been covered before the set will be complete; the principal ones that are lacking are Roofing and Lighting. Specifications for Railway Buildings is, of course, a subject that perhaps can never be finally completed, but we hope to be able to submit it in rather definite form at the next convention.

The subject of Ice Houses and Icing Stations was considered by a Sub-Committee during the year whose report, which the Committee offers as information, will be found as Appendix B, on page 841 of Bulletin 245. Mr. Christiansen, of the Rock Island, Chairman of the Sub-Committee, will present the report.

Mr. Eli Christiansen (Chicago, Rock Island & Pacific) :—We are offering this part of the report as information, this being an entirely new subject. The data contained in this report is merely evidence of buildings that have been constructed. We are not drawing any conclusions as to theory, merely illustrating in a general way what has been done in the construction of ice houses and icing stations.

Chairman Dorrance :—The subject of Floors for Railway Buildings was considered by a Sub-Committee during the year whose report, which the Committee offers as information, will be found as Appendix C, on page 869 of Bulletin 245. Mr. Crable, of the Hocking Valley Railroad, Chairman of the Sub-Committee, will present the report.

Mr. A. Crable (Hocking Valley) :—The Committee would like to say in explanation of its report as submitted that after making an investigation of the subject of floors we found that it was one of considerably greater breadth than we at first supposed. It was therefore decided to be inadvisable and improper to attempt to make a definite and detailed report on such a broad subject, as it was felt that this report would probably not have the merit and the value which the Association would have a right to expect from it. That being the case, the Committee decided to cover the subject in a general way only, with a view of establishing a basis for a more detailed report to be made later. A very brief survey of the results of this study was given in Appendix C, pages 869-72, and is submitted at this time merely as information.

Chairman Dorrance :—The Committee felt that the subject of Freight House Design involved study of elements entering into the proper design of freight house buildings, and that for the preliminary work necessary to establish a working basis, investigation be carried on to greater advantage by an individual rather than by a large committee. Mr. Filippi, of the Illinois Central, undertook this work for the Committee and will present the result of his investigations, which is found in Appendix D, page 873 of Bulletin 245.

Mr. Hugo Filippi (Illinois Central) :—Your Committee was charged with the duty of investigating and reporting on the factors which enter into the design of one-level l.c.l. freight houses, and at this time wishes to direct your attention to a few omissions and one or two corrections as they should appear in the final report published in the Proceedings.

First I direct your attention to page 873, Appendix D. Under the subhead the word "the" in the second line should be changed to "one," and the subhead should read: "A study of the principal factors which govern the design of one-level l.c.l. freight houses."

On page 881 I note the omission of the word "daily" in the fourth line from the bottom. It should be inserted between the word "total" and the word "turnover," and that sentence should read: "Determine what per cent of the total daily turnover is delivered to consignee direct."

To the casual observer the subject of l.c.l. freight house design would appear to be one on which considerable data might be found in current engineering literature. However, such is not the case. The design of freight terminals, particularly in large cities, is becoming a very important one from an economic standpoint and this report covers in some detail the principal factors which govern one phase of the problem, namely, the design of one-level l.c.l. freight houses. A synopsis of the subject covered is indicated on page 876. This report will be submitted merely as information and as a progress report. It is to be hoped that the Committee for next year will be instructed to continue this important work, and thereby be enabled to offer you some definite conclusions on these factors.

Chairman Dorrance:—The Committee has recommended to the Board of Direction that in addition to continuing the uncompleted assignments, the following subjects be given the Committee for investigation and report:

1. Ventilation of Buildings.
2. System for Numbering Railroad Buildings.
3. Design and Specifications for Different Types of Chimneys or Stacks.
4. Economical Types of Ornamental Roof Coverings for Passenger Stations.

During the year the Committee on Outline of Work assigned to this Committee several subjects for investigation as to the possibility of standardization of same. This work was turned over to a Sub-Committee, and I regret that the Chairman, Mr. Rodman, of the New York, New Haven & Hartford, is not here to present their report.

The matter was taken up late in the year and we are not able at this time to offer any definite conclusions, but in Appendix E of our report, page 895, of Bulletin 245, will be found the results of the Sub-Committee's work. Some progress was made in regard to the possibility of standardizing the following:

Size of Window Glass.
Fire Hose.
Fire Nozzles.
Hose Threads.

Work was begun on fire hydrants and scales for baggage rooms. These subjects were assigned to this Committee by the Committee on Outline of Work, but it was found, however, that other committees were handling these two subjects and had progressed further than our Committee, and this Committee therefore dropped them from further consideration. The Committee present this report only as information without any recommendations as to adoption, believing the subject of standardization requires more study than we have yet been able to give it before any definite recommendations can be given.

The President:—It will be received as information. This completes the report of this Committee, and I desire to compliment the Committee for giving us a valuable contribution. It has done considerable work, and they are now dismissed with the thanks of the Association.

DISCUSSION ON RULES AND ORGANIZATION

(For Report, see pp. 983-1025.)

Mr. W. C. Barrett (Lehigh Valley):—The report of the Committee you will find in Bulletin 245, beginning at page 983. The first subject, revision of the Manual, was assigned to a Sub-Committee. Neither the chairman or vice-chairman of that Sub-Committee are here, and I will present the report for them.

It was not the intention of this Committee when we first began our work to present any revision of the Manual this year, but in taking up the work of promulgating rules for conduct of work for signals and interlocking we discovered that the Signal Section of the American Railway Association had formulated rules covering the duties and work of signal maintenance employees and those rules had been approved by the American Railway Association, so that this Committee thought it would be proper for us to go over our rules already in the Manual covering signal maintenance, and make them agree with the rules already formulated by the Signal Section and approved by the American Railway Association. Therefore on pages 985-987 you will find revised rules for duties of Signal Maintainers. There is not a rule in that list but what has already been approved by the American Railway Association, and they are submitted for approval by this Association for printing in the Manual.

I therefore move that the rules for Signal Maintainers be approved by this Association for printing in the Manual.

Mr. C. E. Lindsay (New York Central):—I would like to ask if the Committee considered those rules from a strictly maintenance standpoint, and if there are any objections to them from that standpoint. The signal people, of course, like rules to suit their view, and I wondered if you looked at the rules from that standpoint.

Chairman Barrett:—In reply to Mr. Lindsay I will say that our rules were really gotten up in the first place largely from that standpoint, and the only revision was in order to make them agree with the rules that the Signal Section had promulgated. You will notice some of these rules have only a single number. Those are the ones we promulgated ourselves. The others that are followed by a letter are rules of the Signal Section, and those with a number in parentheses are their rules entirely, so that we have covered that.

(Motion put to vote and carried.)

Chairman Barrett:—The second subject, "Rules for conduct of Bridge and Building, Signal, and Telegraph and Telephone work," was assigned to a Sub-Committee, of which Mr. Barnhart is Chairman, and he will present the report.

Mr. E. H. Barnhart (Baltimore & Ohio):—The rules are shown on page 990 to about the middle of page 992. These rules for the conduct of work were compiled largely from a maintenance standpoint, and, as our Chairman stated, after we had compiled them we found that the Signal Section had also promulgated rules. The rules shown with a double number are the ones that have been adopted by the American Railway Association, and these have been included. They are presented for printing in the Manual.

Chairman Barrett:—I move you that the report as submitted in Appendix B covering Signals and Interlocking, be approved by this Association for printing in the Manual.

(Motion carried.)

Mr. Barnhart:—The balance of the information shown in Appendix B, from pages 992-1002, has been compiled and is presented as information only. When this Sub-Committee endeavored to solve the problem of promulgating rules for the conduct of Bridge and Building work, we found that we were in rather a virgin field, and we do not feel that the information is in such shape as to recommend it to this Association for printing in the Manual. We therefore present it as information, with the request that discussion be given, and we expect to continue the subject next year, conferring with the various committees assigned to those particular subjects.

The President:—It will be received as information.

Chairman Barrett:—Subject 3, "Use of mechanical appliances and tools, and organization of labor involved," was assigned to a Sub-Committee, of which Mr. H. H. Harsh is Chairman. Mr. Harsh will present the report.

Mr. H. H. Harsh (Baltimore & Ohio):—The Sub-Committee on this particular assignment had several meetings during the year. They realized that they had a large field to cover, and we attempted to cover the mechanical appliances that are most common to railway work. The report is covered in pages 1003 to 1025. In handling this work we did not attempt to look into the merits of these machines, nor the cost of handling work by these machines. We merely outlined what the machines are and the organization that will operate those machines. We present this data to the Association as information only, and expect to continue the work during next year.

The President:—It will be received as information.

Chairman Barrett:—You will find the proposed outline of work for the ensuing year on page 984. That completes the report of the Committee for this year.

The President:—The report of this Committee is completed, and the Committee is dismissed with the thanks of the Association.

DISCUSSION ON WOOD PRESERVATION

(For Report, see pp. 899-981.)

Mr. C. M. Taylor (Central of New Jersey):—While we are last we hope we are not least in your minds. While we realize that your minds are pretty well filled with material strictly engineering, when you come to us we hope that you will absorb some preservatives that we have to offer you for timber preservation. We have not got much this year in a constructive way other than to keep in step with the progress of wood preservation. The first problem is the question of the revision of the Manual. This is a revision of the recommended practice for the empty-cell treatment with final vacuum. This was proposed by one of the members of our Committee, and we think it is a revision that should be had in connection with this recommended practice. I move that it be accepted for inclusion in the Manual.

(Motion carried.)

Chairman Taylor:—The next is the report under Appendix B on page 902, "Service test records." Mr. Howard, Chairman of this Committee is not here, and I will endeavor to present this report. I regret very much that Mr. Howard is not here, as it is to my mind one of the best service test record reports that our Committee has ever presented. It has to do with the completed records that have been the result of the coöperation of the Forest Service with different railroads, which are shown on pages 904-5. It has to do with the question as to the advantage of the different kinds of treatment that are used, as shown on page 606. By reference to those figures you will note that our Committee figures that the annual cost of applying the A.R.E.A. formula drops from 41 cents per tie per year to 21 cents per tie per year, in the case of creosoted red oak. This Sub-Committee makes a definite recommendation in the report, but for the account of those who are interested in determining conditions on their railroad, and determining whether they are really making this saving in the matter of treatment, particularly of creosotes on page 908, under "Test Sections," the Committee has six paragraphs, two on the reasons for test sections, and four on how to make test sections, and further five points covering record test sections. Since this was printed there has come up the question of the point that the Tie Committee has made, that they want to use the white oak tie as a test—we are willing that they use the white oak tie as a test as to wood preservers. We think that is of better advantage to us than they possibly think it is, because we have grown to know that white oak is not giving the life that we formerly supposed it did. We are very willing to accept the recommendation of the Tie Committee that the white oak tie be taken as the standard. On the other hand, we believe that the test section on the basis of laying ties out of face, 100 white oak ties alongside of 100 some other kind of ties, is not the check on wood preservation that we would like you to have. Consequently we feel that the word "test" in our work should be changed to "check." In other words, it is our idea and our advice that instead of starting a test section insofar as wood preservation is concerned, that you start a check section. In other words, take a Roadmaster's division and have the Operating Department decide that one section of that Roadmaster's division indicates about the average of his territory, and that you then take that as a check section and keep a record of the ties that are placed and removed from that test section, and thereby get a good idea of what that Roadmaster's division as a whole should do insofar as ties are concerned. We have found by experience on two railroads that that has given excellent results, and we feel that it should be followed up by other roads.

The Committee is almost unanimous on the question of dating all treated ties that go into the track, and we hope that there will be more of it done. Like all other programs of checks on railroad work there have been failures, but these failures are largely due to lack of initiative or lack of control. We have found railroads that have been successfully using dating nails for seventeen years, and who would not give them up. They figure that the moral risk that a section foreman wants to assume if he takes out treated ties before they have given their full service will be much greater if he knows that there are dating nails in those ties, and that they will be checked up by someone in authority to see why the ties did not stay their full life. We trust there will be some discussion on that subject.

On pages 910-933 we have given a record of all tests where the entire tests have been completed. You will find all sorts of conditions, all sorts of track, all the different species of ties listed therein. This is reported and submitted for information.

Mr. F. J. Angier (Baltimore & Ohio) :—If we were all of one mind there would be no need of an association of this kind. Under the heading of "dating ties," the Committee reports that one member does not concur in the recommendation, and as I am that one member, I feel it is my duty to say to you why I do not agree with the Committee on this point. As a whole, I think I agree with the Committee, and we have coöperated, and with the exception of one or two points we are together. I do not believe in stepping backwards. Twenty-two years ago the road with which I was connected were using dating nails, and they placed a dating nail in every treated tie. We kept this up for ten years. For ten years every section foreman sent a report into the office, showing the number of ties removed, the number of ties put in, and what they were removed for. We kept a record of that for ten years and it cost us $80,000. A report was made and the president of the railroad said it was not worth the paper it was written on. There was one division on which 375,000 ties were placed, and this report showed that only three ties had been removed in all that time for all causes, decay, burn, derailment, and everything. We were asked then to discontinue that way of keeping a record of the ties and to insert test tracks, to put dating nails in test tracks only.

I am opposed to putting dating nails in every tie, because the expense is unjustified. This report recommends putting dating nails in all ties. That means every tie, whether treated or untreated. It means that we are using today say 125 million ties. This calls for 125 million nails. At the low estimate of $2.00 a thousand for nails, it will cost the railroads $250,000 for nails alone. To put these nails in the ties will cost at least one-tenth of a cent a nail, when you take into consideration the wasted nails, the nails left over at the end of the year, the transportation on the nails, and all that sort of thing. This will add another $125,000, making the cost to the railroads $375,000 a year to put dating nails in ties, and what good do you get from it?

One member of the Committee says it will satisfy the president and the general manager when he rides over the railroad, because he can get out and look at a tie and he can see the nail in there and see that this tie was in the track for 15 years, and he says that is wonderful. Here is another tie that was in the track for 20 years; it is a wonderful thing; but it will not tell you how many of those ties are in the track. You do not know whether it is 1 per cent or 2 per cent or 10 per cent. I believe in putting dating nails in test track where we can keep a record, but I certainly do not think that the railroads today, as hard pressed as they are for money, want to spend $375,000 putting dating nails in every tie.

Some of the Committee will say it will not cost that much because they are going to use a small dating nail. This Association has a standard dating nail, 22 to the pound, and this is the nail that I am talking about. They have a nail that weighs 104 to the pound. It is just about as big around as a match, and in my estimation it will not last five years. It it untried so far as I know. Why do we want to go to work and put a nail of that kind in a tie when it will not last the life of the tie? I am opposed to this on the ground that we have tried it and we have stopped using them. It is an expense, unjustified, I believe, in putting the dating nail in all ties.

The President:—We will receive this as information and pass to the next subject.

Chairman Taylor:—Before we pass from this subject, in listening to the gentleman you might believe that what he tells you are facts. They are facts insofar as the road on which he started out to put them in, is concerned. That railroad gave up the practice, and that road today cannot give you any real data to show you the life of ties on their system. I asked for it yesterday, and they have not got it. All they have got is a record of some test ties that Mr. Angier put in, and most of them are still in track. If anyone tells you that a test track on any division indicates the life of all the ties in that division, they cannot substantiate the statement. I can pick out ties to go into a track that will outlast me, but I cannot give to my railroad all ties that will outlast me. Why worry about 100 or 200 or 300? What we want to worry about is the 125 million. The railroads that are making the best out of wood preservation today are the railroads that are really putting dating nails into every tie. Just because one railroad that Mr. Angier happened to be connected with made a failure does not mean that there are others that have not made a success of it. We are proud of our wood preservation. As to a section foreman's report on that railroad indicating only three ties removed in ten years, I will let you judge what that indicates. We want something that we can show you that will make ties last 15 or 16 or 20 years. I do not know anything about Mr. Angier's figures—I do not know whether they are right or wrong—but I know a railroad that has been using a good wood preservative for the last 17 years and they tell me that their removals are averaging less than 100 ties per mile per year. If it does not cost more than one cent per dating nail, that means a dollar per mile of track per year.

Our problem is to get you Engineers interested in wood preservation and treated ties. Of course, you will take our word for what we tell you, but we do not want you to take our word; we want you to walk the track and see the ties that are tested. We are submitting this report as information, but we would like to have a vote on the proposition of whether you approve the idea of putting dating nails in all treated ties.

I move that it is the sense of the meeting that dating nails be used in treated ties.

(Motion carried.)

Mr. Angier:—Mr. Taylor says that the test on the Burlington Road was not worth anything at all. I say that the tests on the Burlington Road are the best tests we have in this country today on any railroad. Mr. Taylor would lead you to believe that these tests were a failure, that they were not put in correctly. These tests were put in in 1909. One thousand ties of twenty different kinds of wood were treated in three different ways, and then along with untreated ties were placed in nineteen divisions. They were not selected ties, but we took any ties that came along and put them in the track, the treated and untreated together. They were carefully watched.

I regret to bring this up, but it was unfair to make the comparison that has been made. The zinc creosote tie is given a life of 12.5 years based on a few ties treated in Texas with a quarter of a pound of zinc and three pounds of oil, and they say these will give 12.5 years' life. They do not say anything about the ties on the Burlington or Baltimore & Ohio treated with zinc and creosote. They do not say that these ties will give 14 years' life, but I can prove to you from the tests I have made will give 14 years' life, and to get their figures, they reduce the cost of ties from 41 to 26 cents, and they have used a price of 12 cents for creosote and 9 cents per pound for zinc chloride. Why did not they take the highest price for zinc chloride and the lowest price for creosote in the industry? Why don't they use the price of zinc chloride today, which is less than 6 cents if you want to make a fair comparison?

Chairman Taylor:—It is natural that what Mr. Angier learned on the Burlington he took to the Baltimore & Ohio. He installed on the Baltimore & Ohio the same kind of test tracks. He issued a statement trying to prove he was saving a big bunch of money on the Baltimore & Ohio as the result of the ties in the test track.

The test track on the Burlington is to my mind the best test track in the country, but I was simply defending the position of the Committee in saying that test track is not a criterion on which to base the average life of all the ties in track.

Mr. G. J. Ray (Delaware, Lackawanna & Western):—I think the Committee has taken the right step, for the simple reason that we have been dating our ties for the last twelve years, and we have secured good results. I believe the psychological effect on the section foreman of the dating nail is very great. We propose to continue this practice. We are saving considerable money by it and the practice has the advantage of providing valuable data on tie renewals.

Mr. W. H. Courtenay (Louisville & Nashville):—I have advocated the dating nail, but we had so much difficulty in getting the foremen to drive the dating nails into the ties, that we sent all the dating nails to the tie-treating plant with instructions to the superintendent to drive them at the time of treatment.

Mr, Angier:—Is there a member of the Tie Committee present who can tell us what the recommendation of the Tie Committee is on these dating nails in the ties?

Mr. W. A. Clark (Duluth & Iron Range):—The information collected by the Tie Committee as the result of circularizing the membership a few years ago showed that the majority of the roads that had used dating nails had abandoned the practice, although some of them continued the practice and were in favor of keeping it up. The Tie Committee made no general recommendation covering the use of dating nails.

Chairman Taylor:—The next subject is No. 3, "Preservative treatment for Douglas fir." This will be presented by Mr. Belcher.

(Mr. R. S. Belcher abstracted that portion of the report.)

The President:—This report is received as information. Is there any discussion? If not, we will pass to the next subject.

Chairman Taylor:—The next subect is the "Treatment of Piles and Timbers for Marine Structures." This will be presented by the Chairman.

(The Chairman presented an abstract of Appendix B.)

The President:—This also will be received as information. Is Colonel Atwood present?

Col. Wm. G. Atwood (National Research Council):—The National Research Council was requested to form a committee for the study of the protection of timber against the marine borers and to study the use of all other methods of marine construction than timber. This committee has been appointed and have designated me as the Director of their operations.

These two sub-committees have done extremely valuable work in collecting this information and in presenting it so clearly and the National Research Council Committee hopes that this Association will continue this work in the Committee on Wood Preservation and that this Committee will coöperate and assist us, as we wish to coöperate with and assist you.

It is our purpose as rapidly as we can to initiate biological and chemical studies both of preservatives and of the water in which these animals are found and also to collect all the data we can from Europe, where there has been a study of this problem for 200 or 300 years. We will place this information at the service of this Association, and anyone else who is interested in water-front construction. This study will cover concrete and steel as well as timber. We hope to organize local committees at points where investigation seems to indicate that valuable information can be gained. At these points we will probably request the roads interested to assist us in making our observations. If they have laboratories available they will be asked to give us some assistance from that end. We think it necessary to give much more attention than has been done previously to the biological conditions. The activity of these pests seems to be increasing all over the world. These attacks vary in intensity from year to year and at present they seem to be on the increase. It appears probable that the European worm which is much more virulent than the one we fought on the Pacific Coast, has been found in San Francisco and at Barnegat Bay in New Jersey. The worm we have had in the United States previously will not live in polluted water or in water below a certain degree of salinity, but this imported worm, the teredo navalis, will live almost anywhere. In a letter from the biologist of the San Francisco Committee he stated that this species was thriving in water with such a high sewage pollution that putrefaction was taking place.

We hope that we can develop from the study of biological conditions certain results that will aid us to protect the timber and to write specifications which will assist in the proper construction of concrete in sea water.

We desire to secure the assistance of the Association, the Committee, and the individual members as we have occasion to call on them.

The President:—This portion of the report is submitted as information.

Chairman Taylor:—The next subject is Appendix E—"Research work on Marine Piling." Mr. Atwood's discussion should have been directed to this subject. This is presented as information.

The next subject is shown in Appendix F, "Preservative Treatment to be used on piles and timbers in land construction." This will be presented by Mr. O. C. Steinmayer.

(Mr. Steinmayer abstracted the report.)

Chairman Taylor.—The underscored portion on pages 977 and 978 is offered for adoption and inclusion in the Manual.

(Motion carried.)

Chairman Taylor:—The next subject is shown in Appendix G, "Methods for storing lumber and piling for air-seasoning preliminary to preservative treatment."

I move the adoption of the underscored portion shown on page 979.

(Motion carried.)

That completes our work for the year and we trust our recommendations for future work will be considered by the Board of Direction.

The President:—The Committee is relieved with the thanks of the Association for its valuable report.

REPORT OF
THE AMERICAN COMMITTEE
ON ELECTROLYSIS

1921

Pt-2-A

COMMITTEE

American Institute of Electrical Engineers

Bion J. Arnold, Chairman,	Chicago, Illinois.
N. A. Carle,	Newark, New Jersey.
F. N. Waterman,	New York, N. Y.

American Electric Railway Association

L. P. Crecelius,	Cleveland, Ohio.
W. J. Harvie,	Syracuse, N. Y.
G. W. Van Derzee,	Milwaukee, Wisconsin.

American Railway Engineering Association

E. B. Katte,	New York, N. Y.
Martin Schreiber,	Newark, New Jersey.
W. M. Vandersluis,	Chicago, Illinois.

National Electric Light Association

L. L. Elden,	Boston, Mass.
D. W. Roper, Treasurer,	Chicago, Illinois.
Philip Torchio,	New York, N. Y.

American Gas Association

Walter C. Beckjord,	New York, N. Y.
Charles F. Meyerherm,	New York, N. Y.
H. C. Sutton,	Philadelphia, Pa.

Natural Gas Association of America

Forrest M. Towl,	New York, N. Y.
Thomas R. Weymouth,	Oil City, Pa.
S. S. Wyer,	Columbus, Ohio.

American Telephone and Telegraph Company

A. P. Boeri,	New York, N. Y.
F. L. Rhodes,	New York, N. Y.
H. S. Warren,	New York, N. Y.

American Water Works Association

Alfred D. Flinn,	New York, N. Y.
Nicholas S. Hill, Jr.,	New York, N. Y.
E. E. Minor,	New Haven, Conn.

National Bureau of Standards

Burton McCollum,	Washington, D. C.
Dr. E. B. Rosa,* Secretary,	Washington, D. C.
E. R. Shepard,	Washington, D. C.

* Deceased.

SUB-COMMITTEES

Sub-Committee A—Principles and Definitions

	Representing
F. L. Rhodes, Chairman,	American Telephone and Telegraph Company.
A. D. Flinn,	American Water Works Association.
E. B. Rosa,*	National Bureau of Standards.
W. M. Vandersluis,	American Railway Engineering Association.

Sub-Committee B—Design, Construction, Operation and Maintenance

	Representing
E. R. Shepard, Chairman,	National Bureau of Standards.
Nicholas S. Hill, Jr.,	American Water Works Association.
E. B. Katte,	American Railway Engineering Association.
D. W. Roper,	National Electric Light Association.
H. C. Sutton,	American Gas Association.
G. W. Van Derzee,	American Electric Railway Association
H. S. Warren,	American Telephone and Telegraph Company.
F. N. Waterman,	American Institute of Electrical Engineers.
S. S. Wyer,	Natural Gas Association of America.

Sub-Committee C—Methods of making Electrolysis Surveys

	Representing
Burton McCollum, Chairman	National Bureau of Standards.
A. P. Boeri,	American Telephone and Telegraph Company.
N. A. Carle,	American Institute of Electrical Engineers.
L. P. Crecelius,	American Electric Railway Association.
L. L. Elden,	National Electric Light Association.
Chas. F. Meyerherm,	American Gas Association.
E. E. Minor,	American Water Works Association.
Martin Schreiber,	American Railway Engineering Association.
T. R. Weymouth,	Natural Gas Association of America.

Sub-Committee D—European Practice

	Representing
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W. C. Beckjord,	American Gas Association.
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PREFACE

The preface to the preliminary report prepared by this Committee, and printed in October, 1916, sketched briefly the history of the development and relationship of electric railways to contemporary utilities, so far as the question of electrolysis was concerned, stated the object for which this Committee was formed, pointed out that the report as then issued contained only statements of fact regarding electrolysis upon which all members of the Committee could at that time unanimously agree, and that a later report would be prepared carrying the subject further.

Soon after the publication of the preliminary report the United States entered the World War, and the attention of the members of the Committee was so absorbed in other matters that the work of the Committee was practically suspended until March, 1919. At that date its activities were resumed, with the result that a report is herewith submitted which embodies such statements of fact and descriptions and discussions of methods of electrolysis testing and of electrolysis mitigation as the members of the Committee have to date unanimously agreed upon.

While this report supersedes the preliminary report of 1916, it should, unless the principals see fit to discontinue the work of the main committee, be considered in the nature of a progress report and not as final, as it is impossible at the present time to finally answer many of the outstanding questions involved. Also it is to be understood that the report is confined to the technical and engineering aspects of the subject and does not attempt to deal with matters of policy or with legal questions, such as the rights and responsibilities of the several interests concerned.

At times great differences of opinion between members of the Committee have arisen, but the subjects differed upon have been patiently discussed in subcommittee meetings, and in some cases tests have been made and a final discussion held on the subject by the main committee until unanimity of opinion existed. The results as thus determined are herein recorded.

A summary of Chapter 2 is included in the report for the convenience of users, but if any question should arise as to the proper interpretation of the language, the report itself, rather than the summary, should be considered as governing.

It is believed that the work of this Committee as a whole has resulted in a much better understanding of the subject, and that the application of the knowledge gained by its members and the organizations they represent will aid materially in reducing the destructive effects due to electrolysis.

The Committee, through its Research Subcommittee, has established a close working relationship with the National Bureau of Standards, which has been distinctly advantageous.

The Committee regrets to chronicle the death in Washington on May 17, 1921, of its secretary, Dr. Edward B. Rosa, Chief Physicist of the National Bureau of Standards, one of its most efficient and esteemed members.

October, 1921. BION J. ARNOLD,
Chairman

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Chapter 1

PRINCIPLES AND DEFINITIONS

A. ELECTROLYSIS IN GENERAL

1. **Electrolysis** is the process whereby an electric current passing from an electrode to an electrolyte or vice versa causes chemical changes to take place in the electrolyte. Electrolysis also includes any chemical changes at the surface of an electrode resulting from the chemical changes in the electrolyte. Electrolysis is independent of the heating effect of the electric current.

> NOTE.—These changes usually occur in a water solution of an acid, alkali, or salt. By the passage of an electric current through it, water (containing a trace of acid) is decomposed into hydrogen and oxygen, copper is deposited from a solution of copper sulphate, silver from solutions of silver salts. Electroplating, electrotyping, and refining of metals by electrodeposition are useful applications of electrolysis in the arts. Electrolysis is involved in the charge and discharge of storage batteries, and in the operation of primary batteries.
>
> In order that electrolysis may occur, the following conditions must be present:
>
> (a) There must be a flow of electric current through a conducting liquid from one terminal to another;
>
> (b) The conducting liquid must be a chemical compound or solution which can be altered by the action of the electric current.

2. **Electrolyte, Electrode, Anode, Cathode.** The *electrolyte* is the solution (or fused salt) through which the electric current flows; the conducting terminals are the *electrodes;* the terminal by which the current enters the solution is the *anode;* the terminal by which it leaves is the *cathode.*

> NOTE.—The chemical changes caused by the current may affect both the electrolyte and the electrodes. In the case of a solution of copper sulphate with copper plates as electrodes, copper is removed from the anode by the current and carried into solution; an equal amount of copper is deposited upon the cathode. In general the metal travels with the current toward the cathode.

3. **Amount of Chemical Action.** (*Faraday's Law.*) The amount of chemical action taking place at the anode and also at the cathode (as expressed by Faraday's Law) is proportional to (1) the strength of current flowing, (2) the duration of the current, and (3) the chemical equivalent weights of the substances.

> NOTE.—Otherwise expressed, the quantity of metal or other substance separated is proportional to the total quantity of electricity passing and the electro-chemical equivalent of the substance or substances concerned. The electro-chemical equivalent of a metal is proportional to its atomic weight divided by its valence. Faraday's Law is so exactly realized in practice under favorable conditions that it is used as the basis for the definition of the international ampere, one of the fundamental electrical units. (See Passivity, Paragraph 15.)

4. **Cause of Current Flow.** The current flowing through the electrolyte may be due (1) to an external electromotive force or (2) to the difference of potential due to the use of electrodes of different materials or to solutions of different concentrations.

Note.—The first case is illustrated by electrolysis of dilute sulphuric acid using two lead plates and an external battery; the second by the electrolysis of the same solution using a zinc and a copper plate, which touch each other inside or outside the solution. The first occurs in charging a storage battery; the second in the discharging of a primary battery or a storage battery.

5. **Electrolysis by Local Action.** Instead of two plates of different metals the same result may follow with *one plate* if it is chemically impure or otherwise heterogeneous, when immersed in an electrolyte.

Note.—Such a plate excites local currents and a loss of metal occurs at all the anode areas. This *local action* causes impure zinc to dissolve rapidly in a solution which has no action on pure zinc.

6. **Anodic Corrosion** is the term applied to the loss of metal by electrolysis at the anode.

Note.—When iron is anode the iron is carried into solution by the current, the first product being a salt of iron, the nature of which depends upon the character of the electrolyte. In dilute sulphuric acid, ferrous sulphate is formed; in hydrochloric acid, ferrous chloride, etc. These first products of electrolysis are frequently modified by *secondary reactions.*

7. **Secondary Reactions** are the chemical changes which occur at or near the electrodes, by which the primary products of electrolysis are converted into other chemical substances, and are sometimes followed by other reactions.

Note.—Ferrous hydroxide formed by the union of iron with hydroxyl ions set free at the anode, is subsequently converted into an iron oxide due to the reactions with oxygen dissolved in the electrolyte. When lead is cathode in an alkali soil or solution, the alkali metal (such as sodium or potassium) reacts with water at the cathode and forms alkali hydroxide, setting hydrogen free. This hydroxide may react with the lead chemically and form lead hydroxide (especially after the current ceases), which in turn may combine with carbon dioxide, forming lead carbonate.

8. **Cathodic Corrosion** is the term applied to the corrosion due to the secondary reactions of the cathodic products of electrolysis, as described in the preceding paragraph. The metal of the cathode is not removed directly by the electric current but may be dissolved by a secondary action of alkali produced by the current.

Note.—The anodic corrosion is more common and more serious; cathodic corrosion, however, sometimes occurs on lead and other metals that are soluble in alkali. Cathodic corrosion never occurs in the case of iron.

B. ELECTROLYSIS OF UNDERGROUND STRUCTURES

9. **General.** As used in this report, the term "electrolysis" embraces the entire process of accelerated corrosion of underground metallic structures due to stray current. In the electrolysis of gas and water pipes, cable sheaths, and other underground metallic structures, and the rails of electric railways, the moisture of the soil with its dissolved acids, salts, and alkalis is the *electrolyte,* and the metal pipes, cable sheaths and rails are the *electrodes.*

NOTE.—Wherever the current flows away from the pipes they serve as anodes and the metal is corroded. Metal or gas or alkali, according to the nature of the soil, will be set free at the cathode.

10. **Self Corrosion** is the term applied when a pipe or other mass of impure or heterogeneous metal buried in the soil is corroded *due to electrolysis by local action.*

NOTE.—This is called "self corrosion" because the electric current originates on the metal itself, without any external agency to cause the current to flow. Self corrosion may also be due to direct chemical action.

11. **Acceleration of Local or Self Corrosion.** Self corrosion is accelerated by the presence in the soil water of *acid* or *salts* which lower its resistance as an electrolyte, and also by cinders, coke or some other conducting particles of different electric potential which augment the local electric currents. In the latter case the metal need not be heterogeneous.

NOTE.—A pipe may be destroyed in a relatively short time by self corrosion or local action if buried in wet cinders or in certain soils.

12. **Stray Current** is that current which has leaked from the return circuit of an electric railway system and flows through the earth and metallic structures embedded therein.

13. **Anodic and Self Corrosion.** Anodic corrosion due to stray currents and self corrosion due to local action may occur simultaneously, and *the former may accelerate the latter.*

NOTE.—Hence the corrosion due to a given current plus the increased self corrosion induced by that current may give a greater total corrosion than called for by Faraday's Law. This explains how the coefficient of corrosion may exceed unity.

14. **Coefficient of Corrosion.** The coefficient of electrolytic corrosion (sometimes called corrosion efficiency) is the quotient of the total loss of metal due to anodic corrosion (after deducting the amount of self corrosion if any) divided by the theoretical loss of metal, as calculated by Faraday's Law, on the assumption that the corrosion of the anode is the only reaction involved.

NOTE.—In practice it is found that the coefficient of corrosion varies widely from unity, being sometimes as low as 0.2 and sometimes even above 1.5, but commonly between 0.5 and 1.1.

15. **Passivity** is the name given to the phenomenon in which a current flows through an electrolyte without producing the full amount of anodic corrosion which would occur under normal conditions.

NOTE.—This restricted definition of passivity has regard only to its effect in electrolysis. Many conditions affect the degree of passivity attained, an initial large current density being favorable to it. Plunging iron into fuming nitric acid renders it temporarily passive. A satisfactory explanation of passivity has not been given.

16. **Polarization Voltage** (sometimes called polarization potential) is the temporary change in the difference of potential between an electrode and the electrolyte in contact with it due to the passage of a current to or from the electrode. This change in potential difference is due to the change in the conditions of the surface of the electrode or change in the concentration of the electrolyte (or both), and under some conditions is approximately proportional to the current flowing, but in many cases is not so proportional. The magnitude of the polarization voltage also depends on the material of the electrode, the nature of the electrolyte, and the direction of the current.

17. **Alternating or Frequently Reversing Direct Currents.** If alternating currents (or frequently reversing direct currents) flow through the soil between pipes or other underground metallic structures, the metal removed during the half cycles when a pipe is anode may be *in part replaced* when it is cathode. Hence, the total loss of metal on a given pipe may be less than is indicated by computing the loss on the basis of the positive part of the cycle only, and in the case of alternating current at commercial frequency may be less than 1 per cent. of such computed values.

NOTE.—In slow reversals of current the recovery effect is less, but the loss will be less than with direct current continuously in the same direction (excepting possibly where the phenomenon of passivity may affect the result).

18. **Action on Underground Metallic Structures.** Faraday's Law applies to electrolysis of metallic structures in soil as elsewhere, the total chemical action being proportional to the average current strength and the time the current flows and to the electrochemical equivalent of the metal or other substances concerned. Although local action and passivity affect the loss of metal and so apparently modify Faraday's Law, it is still true that the total chemical action resulting from the current flow is proportional to the total current when local currents are included.

NOTE.—Sometimes this chemical action is concerned only with corroding the anode; sometimes it is concerned with breaking up the electrolyte, as when the anode is a noble metal or in the passive state (as iron and lead sometimes are); sometimes both these effects occur.

The theoretical loss of iron per year per ampere is about twenty pounds and of lead is 3.7 times this amount, or about seventy-four pounds. The loss in volume of lead is 2.4 to 2.6 times that of iron. The greater loss in lead is due to the higher electrochemical equivalent of that metal.

19. Electrolysis Mitigation. The two primary features of electrolysis mitigation are (1) the reduction of the flow of current through the earth and the metallic structures buried in the earth, (2) the reduction of the anode areas of such structures to a minimum, where the current is not substantially eliminated in order to reduce the area of destructive corrosion as far as possible.

NOTE.—The current in the underground metallic structures will be decreased, other conditions remaining the same, by (1) increasing the conductance of the return circuit, (2) increasing the resistance of the leakage path to earth, (3) increasing the resistance between the earth and the underground metallic structures, (4) increasing the resistance of the underground metallic structures.

The anode areas of the underground metallic structures will be decreased, other conditions remaining the same, by providing suitably placed metallic conductors for leading the current out of the underground structures so that the flow of the current directly to the earth shall be minimized. This will change a portion of the anode area to cathode.

20. Electrolysis Survey. An electrolysis survey is the operation of determining by means of proper measurements all relevant facts pertaining to electrolysis conditions, such as the voltage drop in the grounded railway return; the location and extent of the areas in which the metallic structures are in danger from stray currents; the condition of the structures and adjacent soil in the danger areas, and the extent of any damage that may have occurred; the seriousness of electrolytic action in progress and the source of the stray current producing the damage, its course and magnitude and the conditions in neighboring structures tending to produce electrolysis. It will generally be found desirable to make some preliminary tests for the purpose of indicating the lines along which the complete survey should be made.

21. Overall Potential Measurements. Overall potential measurements are measurements which are made to determine the difference in electric potential between points in the tracks at the feed limits of the station and the point in the tracks which is lowest in potential, and are obtained by means of pressure wires and indicating or recording voltmeters. This is most commonly applied to measurements of voltage between the point of lowest potential in the grounded portion of a railway return system and the points of approximately highest potential on its various branches.

22. Potential Gradient. A potential gradient is the voltage drop per unit of length between two points on a single conductor or in the earth, and is usually expressed in volts per thousand feet.

23. Potential Difference. In electrolysis work the term "potential difference" usually means the difference in potential which exists between nearby points on separate systems of conductors, or between conductors and the earth, e. g., between pipes and rails, lead sheaths and rails, lead sheaths and earth, etc.

24. Arithmetical Average. The arithmetical average value of a current or potential is the average value of all the instantaneous values of the same polarity.

25. Algebraic Average. The algebraic average value of a current or potential is the algebraic sum of all the instantaneous values, divided by the number of such values.

26. Positive and Negative Areas. *Positive areas* are those areas where the current is in general leaving the pipes or other underground metallic structures for the earth. Such areas are often called *danger areas.*

Negative areas are those areas where the current is in general flowing to the pipes or other underground metallic structures.

Note.—As the current often flows from one underground metallic structure to another, it is evident that within a positive area there are local negative areas and vice versa. Hence the terms are applied somewhat loosely, and according to which condition predominates.

Besides the positive and negative areas there are areas of more or less indefinite extent in which the current flow between metallic underground structures and earth normally reverses between positive and negative values. These areas are called *neutral areas* or *neutral zones.*

27. Drainage System. A drainage system is one in which wires or cables are run from a negative return circuit of an electric railway and attached to the underground pipes, cable sheaths or other underground metallic structures which tend to become positive to earth, so as to conduct current from such structures to the power station, thereby tending to reduce the flow of current from such structures to earth.

Note.—Three kinds of drainage systems may be distinguished: (1) where direct ties with wires or cables are made between underground metallic structures and tracks, (2) where uninsulated negative feeders are run from the negative bus to underground metallic structures, (3) where separate insulated negative feeders are run from the negative bus to underground metallic structures, or a main feeder with taps to such structures.

28. Uninsulated Track Feeder System. An uninsulated track feeder system is one in which the return feeders are electrically in parallel with the tracks. Under such circumstances the cables may be operating very inefficiently as current conductors and as a means of reducing track voltage drop, particularly where voltage drops in the grounded portion of the return are maintained at the low values usually required for good electrolysis conditions. (See Chapter 2, Reinforcement of Rail Conductivity.)

29. Insulated Negative Feeder System. An insulated negative feeder system, sometimes called an insulated return feeder system, or insulated track feeder system, is one in which insulated wires or cables are run from the insulated negative bus in a railway power station and attached at such places to the rails of the track as to take current from the track and conduct it to the station in such a manner as to reduce the potential gradients in the tracks and the differences of potential between underground metallic structures and rails, thereby reducing the flow of current in underground metallic structures. (See Chapter 2, Insulated Negative Feeder System.)

NOTE.—The insulated negative feeders may run separately from the negative bus to various points in the track network, or a smaller number of cables may be used with suitable resistance taps made to tracks at various places.

With this system the drop of potential in the track feeders is independent of the drop of potential in the tracks.

Chapter 2

DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE

The practical electrolysis problem is due to stray current from electric railways. Instances of stray direct currents from other sources sometimes occur, but such cases are not specifically considered in this report.

Currents straying to earth from electric railway tracks frequently find their way to water and gas pipes, telephone and power cables, and other underground structures. When this current leaves these structures through earth, corrosion results. Thus not only are the structures of many different companies subject to injury, but by reason of the different public services dependent on such structures, the public as a whole has a direct interest in this type of electrical interference. The problem, therefore, is one which is pre-eminently adapted to co-operative treatment.

In many cities it has been found advantageous to form joint committees, composed of technical representatives of the several utilities concerned, to investigate the local electrolysis situation and determine by agreement a course of procedure to be followed. Such committees should attack the problem in an open and fair-minded manner with the object of effecting, in the most economical way, mitigation of all the troubles resulting from the presence of stray currents in the earth, including corrosion, fire and explosion hazards, heating of power cables, and operating losses and difficulties. To this end, they should be composed of men, or have men associated with them, who are trained in the technique of electrolysis. Active committees of the kind described are now existent in Chicago, Kansas City, Omaha, St. Paul, New Haven, Milwaukee, and Syracuse. The principle of co-operation has been recognized by the Railroad Commission of Wisconsin in an order authorizing an Electrolysis Committee in the City of Milwaukee. Such committees act as clearing houses of information and keep all the interested companies informed as to changes in their systems which may affect the electrolysis situation. Under the direction of such a committee joint electrolysis surveys may be conducted and unified methods of mitigation installed and maintained.

The magnitude of stray currents is determined by the design, construction, maintenance, and operation of the railway system. In general, the same factors that determine the amount of stray currents are those that have a direct bearing on the economy of railway operation. A good example is that of an insufficient number of substations, which results both in large stray currents and poor railway economy. Similar results follow from defective bonding, rails of inadequate size, or failure to interconnect tracks. For this reason, it is believed that many existing railway systems can be modified in such a way as to increase their own economy of operation, while at the same time securing important reduction in stray current. Measures of this character, which are essential to the most economic operation of the railway, should be regarded as a prerequisite of the application either to the railway or to the affected structures, of measures specifically for electrolysis mitigation.

Prior to the consideration of measures for electrolysis mitigation, the following features should be given due attention:

1. Measures Tending Both to Railway Economy and the Reduction of Stray Current.

(a) The return system, including track bonding, should be put in proper condition.

(b) The number of substations should be made a maximum consistent with railway economy.

2. Measures Employed Solely for Electrolysis Prevention.

Where necessary to effect a still further reduction in electrolysis below that provided by the most economic railway system one or more of the following measures should be taken:

(a) *Applicable to Railways.* (1) Additional substations, (2) Insulated negative feeders, (3) A modified system of power distribution such as a three-wire system.

(b) *Applicable to Affected Structures.* (1) Insulating joints in pipes and cables, (2) Insulating coverings for pipes.

(c) *Interconnection of Affected Structures and Railway Return Circuit.* (1) Electrical drainage of cable sheaths, (2) Electrical drainage of pipes.

I. RAILWAYS

A. FEATURES WHICH AFFECT ELECTROLYSIS CONDITIONS

1. Track Construction and Bonding.

(a) *Importance of Rail Circuit.* Stray current is increased by insufficient rail weights and imperfectly bonded track joints. While the major portion of the current of a grounded return railway generally returns through the tracks and return feeders to the power station, a portion finds a parallel path through the earth and its buried metallic structures. As the current flowing in each path is inversely proportional to the resistance of that path, it is of prime importance to make the resistance of the track circuit as low as possible by the use of rails of adequate weight and proper bonding.

(b) *Rail Bond Resistance and Tests.* The contact resistance of the bond terminal connection to the rail may be a considerable part of the resistance of the joint if the bond is not properly installed and maintained, and it is therefore essential in selecting the type of bond to be used, that special consideration be given this feature.

It is the usual practice to measure the resistance of the bonded joint including three feet of rail in terms of a length of continuous rail. The equivalent length of a properly bonded joint including three feet of rail, varies from 3 to 6 feet, depending upon the size of the rail, and the type, length and cross sectional area of the bonds. On some electrified steam roads it is the practice to bond so that the joint alone will have an equivalent resistance of 20 inches of continuous rail and to rebond when this resistance increases to 42 inches. On street railway systems bonding to an equivalent length of 3 to 6 feet is common practice where short bonds are used, rebonding when the joint resistance including three feet of rail increases to that of 10 feet of rail. A single No. 0000 long bond installed around the splice plates will have, with three feet of rail, a resistance equivalent to from 8 to 15 feet of continuous rail, depending upon the size of the rail.

Practice varies widely as to the frequency of testing rail bonds, but most railway companies make complete tests of all bonds at least once each year and more frequent tests on tracks subject to excessive traffic or deterioration. Good practice would require annual tests of all bonds, and semi-annual on tracks in which the bond failures exceed five per cent annually.

(c) *Types of Bonds.* Bonds may be classified according to the method of fastening them to the rails as follows:

(1) Soldered.
(2) Brazed or Welded.
  Resistance Weld.
  Electric Arc Weld.
  Oxy-Acetylene Weld.
(3) Pin Expanded.
(4) Compressed Terminal.
  Solid Single Terminal.
  Single or Multiple Stud.

There is a further distinction between exposed and concealed bonds, the latter being used where the prevention of theft is a serious consideration, in which case the bonds are installed underneath the splice plates.

Local conditions will largely determine the type of bonding to be used. Consideration should be given to the economy of construction, maintenance costs, facilities for using bonding equipment, tools, etc. In recent years there has been a marked tendency toward the more general use of all types of welded bonds with almost complete abandonment of soldered bonds and those mechanically applied to the head of the rail. Pin-terminal and compressed-terminal bonds are still extensively used for application to the web of the rail, but even here the welded type is finding favor with many companies. One reason for the increasing use of oxy-acetylene and electric alloy welded bonds is to be found in the lighter, cheaper, and more portable tools for their application, some of the newer methods and apparatus which have been developed for this class of work being far superior to those formerly employed.

Soldered Bonds are applied to the head, base or web of the rail by means of solder, a blow torch being used to heat the rail to a soldering temperature. The difficulty of securing a permanent and low resistance contact has caused practically all railway companies to abandon this type of bond.

Brazed or Welded Bonds are applied either by the use of the heating effect of an electric current or arc or an oxy-acetylene gas flame.

The Resistance Weld of bond to rail is accomplished by clamping a carbon block against the head of the bond and heating this block to a high temperature by the passage of a large electric current or by drawing an arc on the face of the block.

In the *Electric Arc* process the arc is drawn directly on the rail and bond terminal. In both the resistance and arc methods of welding or brazing the rail and bond terminals are brought to a welding or brazing heat and united in a solid mass by filling in metal, thus forming a mechanical and electrical union. The filling in metal may be a copper or iron wire used as an electrode. When the bond terminal is steel, the latter metal is used. Several methods, differing somewhat in the equipment used and the methods of applying the heat to the bond and rail, are in use, and the selection of the most suitable of these will depend upon a number of factors and often upon local conditions.

The *Oxy-Acetylene* process is similar to arc welding except that the heating is accomplished by means of an oxy-acetylene gas flame from a blow torch.

These methods give a connection of low resistance and short bonds can be applied to the head of the rail without much danger of theft due to the small amount of copper involved and the tenacious contact between bond and rail.

Pin Expanded Terminal Bonds have a hole in each terminal through which a tapered drift pin is driven to expand it into a hole drilled in the web of the rail, after which a pin, slightly larger than the drift pin, is driven into the hole and left there to prevent contraction. This type of bond requires great care and accuracy in manufacture and in installation, but when properly installed makes a very efficient and satisfactory construction. The essential features are a carefully and accurately milled terminal and a perfectly clean, circular-drilled hole, reamed to proper diameter, in the rail. Care should be used to brighten the terminal with emery paper just before installing and to avoid contact with the fingers, which will cause corrosion between the terminal and the rail. Holes should be drilled dry and bonding should not be done except in fair weather so there will be no moisture to induce corrosion. This type of bond is usually applied to the web of the rail. As it requires only small portable tools it has been found to be particularly well adapted to main line tracks under operating conditions.

Compressed Terminal Bonds are of two kinds, one being a single solid terminal bond applied to the web of the rail in a manner similar to the Pin Expanded Terminal bonds described above except that contact with the rail is secured by means of a heavy screw or hydraulic compressor applied to each end of the terminal, causing it to compress longitudinally and expand laterally, bringing the copper into firm contact with the steel. The screw compressors used for compressed terminal bonds are objectionable where fast traffic is maintained on the tracks, as they clamp over the head of the rail, making a dangerous condition due to the possibility of causing derailment. The other is a single or multiple stud terminal bond applied to the head of the rail, the terminal studs being set in holes and expanded into contact by hammer blows. This type of bond has been largely superseded by the modern types of brazed and welded head bonds.

(d) *Welded Rail Joints.* The difficulties and uncertainties attending the proper maintenance of rail joints and bonds have been eliminated to a large degree by the successful use of several modern types of welded joints, such as electric resistance and arc welding, cast welding, and thermit welding. The welded joint in one form or another has been adopted as a standard of construction in nearly every large city in the United States. Most types of welded joints have a conductivity equal to or greater than the continuous rail and are less subject to failure than any form of rail bond. They must be considered, therefore, as a most important factor in the reduction of stray current.

Electric Rail Welding is performed by clamping heavy iron bars to the web of the rail and bringing the bars and the adjacent rail to a white heat by means of an electric current. The process requires a heavy and expensive plant, and is usually carried out by contract on a comparatively large scale. For this reason it is not well suited to installations on small systems. It is well adapted to the reclaiming of old track as well as for new work and has been applied on open T-rail construction where expansion joints are installed at intervals to provide for expansion and contraction.

Arc Welding. There are several forms of arc welding where the splice bars are welded to the rail at a number of points by the use of an electric arc. Electric arc welding may be done under traffic conditions, and is more extensively used in maintenance work than other methods.

Cast Welding is accomplished by setting a mold around the rail joint and pouring molten iron from a crucible around the joint. This process requires transporting a portable cupola along the street adjacent to the work. On account of the improvement in similar types of joints with more portable equipment, this method is not now used as much as formerly.

The *Thermit* process is a modification of the cast weld, the iron being liberated at white heat from a mixture of iron oxide and aluminum, which is ignited in a crucible. Cast welding is used chiefly on new construction and cannot be done under traffic. The renewal of a cast weld joint requires cutting in a short length of new rail which adds another joint to the track.

(e) *Cross-bonding.* The important objects of cross-bonding are to equalize the current flow between the rails, thus reducing the voltage drop and also to insure continuity of the return circuit in case of a broken length of rail or a broken bond in any rail. It is good practice to place cross-bonds at intervals of 1,000 to 2,000 feet on suburban railways and not to exceed 500 feet on urban railways. Cross-bonding between parallel tracks is in some cases installed with the same frequency as between the rails of the single track; in other cases at less frequent intervals. Some companies make a practice of installing cross-bonds under each feeder tap to the trolley wire or at every fourth or fifth span wire, thus enabling them to conveniently preserve a record of their locations. In cases where the track has been carefully insulated cross-bonds should preferably be rubber insulated so as to increase their electrical resistance to earth, and where subject to damage from track tools and to other mechanical injury the insulation should be protected by circular loom or conduit.

The common practice of electrified steam railroads is to use cross-bonds with a conductance equal to one track rail, or of about 1,000,000 circular mils cross-section. Street and interurban railways employ bonds having a cross-section of from 200,000 to 500,000 circular mils.

(f) *Special Track Work Bonding.* It is good practice to provide jumpers at switches, frogs and at other special track work to insure that the electrical continuity of the bonded rail will be maintained. This is usually accomplished by jumpers extending around the special work, and in such cases the frogs are bonded into the track system, or where practicable the special work is bonded as other track rails. The size of the jumper cables to be used will depend upon the nature of the traffic. On tracks bearing heavy traffic a separate cable is usually provided for each rail, while for light traffic a single jumper connecting to all rails on both sides of the special work is sometimes used. In all cases the jumpers should be proportioned to the current carried in the track and in no case less than a No. 0000 for one track.

In cases where the track has been carefully insulated the best practice provides for the use of insulated cables for jumpers, except in dry locations, as for instance, on bridges or on other elevated structures where the ties are not in contact with earth or ballast. The electrical leakage from one bare track jumper to damp earth has been known to offset the effect of many miles of most careful track insulation. Under such conditions, if positive to the earth, the bond is gradually destroyed by electrolysis.

(g) *Bonding Tracks with Signal Systems.* In determining the location of cross-bonds and jumpers in connection with alternating current track signal circuits, a departure from ideal spacing becomes necessary, owing to the fact that cross-bonds are permissible only at the reactance bonds. The signal reactance bonds are located between the signal block sections, and these sections are more or less fixed for train operating conditions. The method used where tracks carry heavy currents is to cross-bond at all signal reactance bonds and install additional cross-bonds with reactance bonds at intermediate locations to obtain the most satisfactory resistance conditions in the sections fixed by the signal system.

(h) *Conductivity and Composition of Rails.* The conductivity of the track rails used by several interurban and electrified steam railroads has been found to be equivalent to about 1/11 that of copper, and this figure generally holds approximately true for girder types of rails, except when alloy steel is used, in which case higher resistivities are found. The track rails are specified for their mechanical qualities, and where these interfere with the electrical requirements, it is customary to give the mechanical qualities preference. The composition of rails for heavy service used by one of the large electrified steam railroads, in percentage, is as follows:

Carbon	0.62 to 0.75
Manganese	0.70 to 1.00
Silicon	0.10 to 0.20
Phosphorous	Not to exceed 0.04

The American Railway Engineering Association has adopted the following composition for heavy rails:

	Class A Rails	*Class B Rails*
Carbon	0.60 to 0.75	0.70 to 0.85
Manganese	0.60 to 0.90	0.60 to 0.90
Silicon	Not more than 0.20	Not more than 0.20
Phosphorous	Not more than 0.04	Not more than 0.04

2. Track Insulation.

(a) *Degrees of Insulation.* Under this sub-heading have been considered, (1) Substantial Insulation, in which the type of construction largely prevents the escape of stray current, and (2) Partial Insulation, which comprises using such means as are available to insulate from the earth the running rails of ordinary street railways in so far as practicable.

Substantial Insulation. Interurban and electrified steam roads generally require the rail to be supported on wooden ties set in well drained broken stone or gravel ballast. Such construction affords a very high resistance between the tracks and earth and reduces the danger of electrolysis to a minimum.

With 10 volts between rail and ground the leakage in some instances is found to be as low as 0.00016 amperes per rail per tie under dry weather conditions, increasing to 0.0055 amperes when wet. On double track with ties spaced 2 feet apart these values represent 0.32 and 11.0 amperes, respectively, per 1,000 feet, or 31 and 0.91 ohms respectively for 1,000 feet. On steel structures where the ties are only partially in contact with the ground and cannot become waterlogged, this leakage is even less. The substantial insulation of a ballasted roadbed has, in some installations, been rendered ineffective by bare negative cables in damp earth or by metallic connections between the tracks and steel supporting structures. Conditions are found to be very favorable for rail insulation where the tracks are in subways or under cover protected from the weather, permitting the ballast and ties to become permanently dry.

Partial Insulation. Tracks placed in city streets where rails are depressed to the surface of the ground and have only their upper surface exposed can be but partially insulated. The character of the material in immediate contact with the rails has a large influence on the resistance to ground, but it has been repeatedly demonstrated that coating the rails with an insulating material is not advisable, and the best plan is to provide a roadbed, which, taken as a whole, is of an insulating character. The use of well drained broken stone or gravel ballast results not only in a good roadbed, but also affords a much higher resistance to the escape of stray current than does a roadbed of concrete. It is desirable to keep vegetation down and otherwise keep the ballast dry and prevent foreign material from washing into it. Salt, which is frequently used to prevent freezing at switches and frogs, greatly increases the conductivity of the roadbed and thereby facilitates the escape of stray current.

Electric railways have experienced some damage due to the corrosion of the base of the rail or of elevated structures connected to the rails in districts where the stray current leaves the structure for the earth. Cases are on record where this corrosion is serious and where steps have been taken to reduce the damage to elevated structures by insulating the rail from the steel structure. Any measure which tends to insulate the track from the soil or any mitigative system which tends to reduce stray current will tend to retard the electrolytic corrosion of the base of the rails and other grounded steel structures.

(b) *Leakage to be Expected.* Under conditions of substantial insulation and where the roadbed is of open construction the leakage varies widely, depending upon the character of the ballast and whether it is wet or dry. In dry weather the resistance may be from 10 to 15 ohms or even more per 1,000 feet of single track. In wet weather this may drop to 3 to 5 ohms. If ties are treated with a 3 to 1 mixture of gas oil and creosote, the resistance may be double the above values whereas with ties treated with zinc chloride or other chemical salts the resistance may be one-half of these values.

The leakage where tracks are only partially insulated will not only be much greater than where they are substantially insulated but will vary over a much wider range. This is because the type of roadbed, character of soil, and drainage conditions vary greatly. It is known that well drained crushed stone ballast with a Tarvia finish will have a resistance from 2 ohms to 5 ohms per 1,000 feet of single track. On the other hand the resistance of roadbeds with solid concrete ballast in contact with the rails and also earth roadbeds, in which the ties are embedded and therefore in a more or less moist condition, are much lower and may be only from 0.5 to 1.5 ohms for 1,000 feet of single track.

3. Reinforcement of Rail Conductivity.

Early track construction practice in this country often included bare wire laid between the rails and connected to each bond. Sometimes one such wire was used for each rail, sometimes one for each track, and sometimes one served for a double track. The wires varied from No. 4 to No. 1, and were either of copper or galvanized iron. Their conductivity was small and they were subject to electrolytic corrosion and mechanical injury. This construction has practically gone out of use. It is, however, common to find the rails in the vicinity of supply stations supplemented by large conductors connected in parallel with the rails. This is not infrequently accomplished by the use of bare copper wire or cable buried between rails, and hence in full contact with the earth. Old rails, bolted and bonded together and buried beneath or beside the track, have also been used in some cases. Such buried conductors increase the leakage from the tracks and should be avoided.

Supplementary conductors in parallel with the track and connected to it at frequent intervals tend greatly to insure the continuity of the return circuit, where the track bonds cannot be well maintained. Where copper cables are so used the occasional failure of bonds does not materially affect the track drop and their use may be justified where tracks are laid on filled or spongy ground or where the proper maintenance is unusually difficult.

Buried bare conductors, however, increase the contact area between the return circuit and the earth, and the tendency to augment stray currents thus caused offsets to a greater or less extent the benefits attained by the reduction of drop.

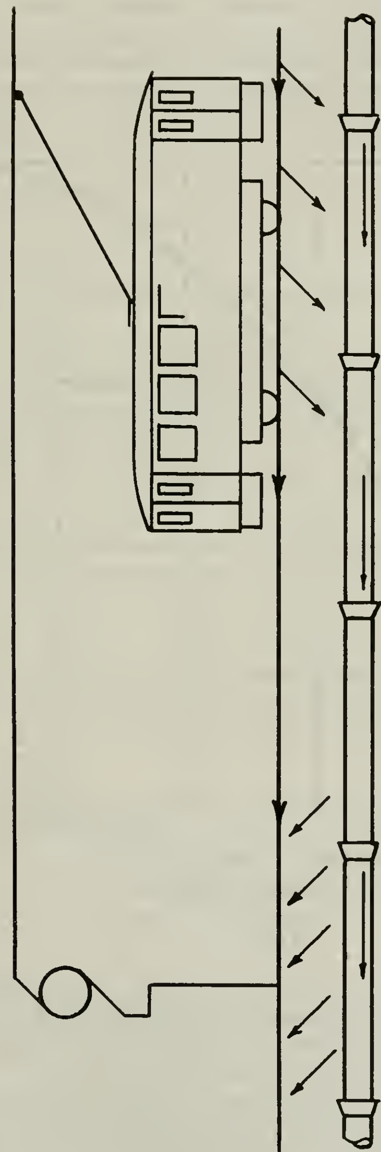
Copper installed in this manner is in parallel with the rails, and therefore has the same drop as exists in the rails. As track gradients rarely exceed two or three volts per thousand feet, this would mean that the drop on such cables would not exceed two or three volts per thousand feet, which corresponds to a current density of about 190 or 280 amperes respectively, per 1,000,000 circular mils. It will be seen that these densities are so low that such use of the copper is very uneconomical, and for this reason this method of reinforcement of the rail conductivity should not ordinarily be used.

Conductors are regarded as being in parallel with the rails when both ends are connected to the tracks or when one end is connected to the track and the other to a station busbar which is connected directly to the rail by a conductor of negligible resistance. The use of such conductors should not be confused with the insulated negative feeder system.

4. Power Supply.

Among the various features of railway construction which tend to reduce stray current none has made more rapid advancement during recent years than the development of multiple feeding points, principally from use of additional substations supplying the railway systems. Increasing the number of substations will reduce the feeding distances and effect a saving in distribution copper and in line and return losses, and will also reduce the amount of current to be returned to any one point. The general effect is to reduce the track voltage drops, thereby reducing the amount of current which will stray from the rails to subsurface metallic structures.

The ordinary street railway system employs direct current at from 550 to 750 volts. Some interurban lines operate at 1,200 volts direct cur-



Single Trolley Electric Railway Showing Paths of Return Current.

Fig. 1.

rent and voltages as high as 3,000 volts are used on the electrified sections of some railroads.

(a) *High Voltage D. C. Railways.* Railway systems of higher potentials than the ordinary 550-750 volt systems may cause more or may cause less stray currents than the latter, depending upon conditions. With the same spacing of substations the current will be less in proportion as the voltage is greater. Usually, however, advantage is taken

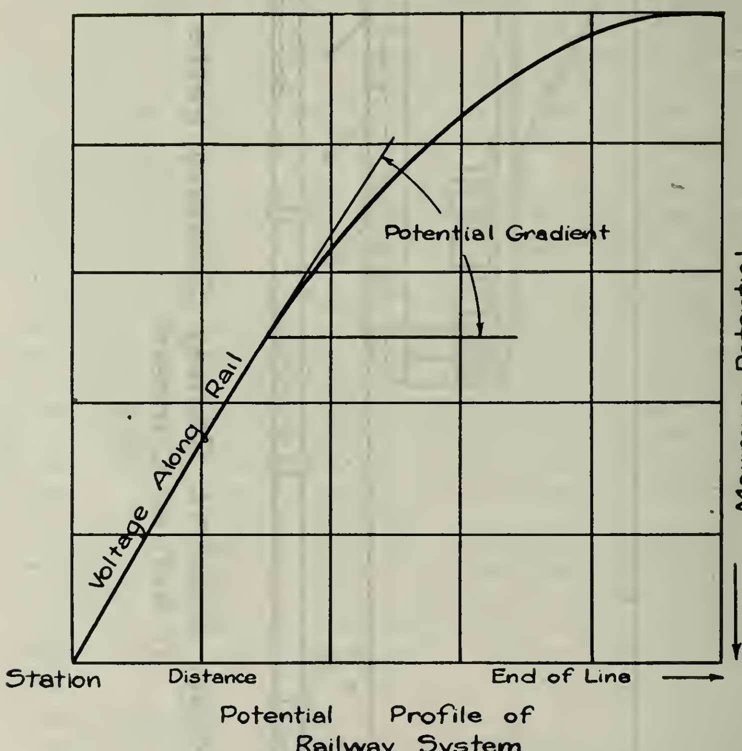


Fig. 2.

of the higher potential to locate the power supply stations farther apart, maintaining approximately the same current density in the tracks with the usual potential gradient. This, of course, results in increased overall voltage drops which tend to increase the stray currents.

In making comparison of high voltage and low voltage systems from an electrolysis standpoint, the difference in conditions must be taken into account. As a rule high voltage direct current is used principally on roads having a private right-of-way with rails on ties supported on well drained rock ballast. Moreover, the major portion of such lines is located in country districts with no buried metallic structures paralleling them, but in some cases such lines pass through cities or towns, or at least enter their suburbs, in which event suitable measures to prevent injury by electrolysis should be taken.

(b) *Source of Stray Currents.* A single trolley electric railway system with an adjacent buried pipe line is illustrated in Fig. 1, in which the underground network of pipes is represented by a pipe parallel to the tracks. At points remote from the power supply station, the current which reaches the rails from the cars will divide between the several possible paths, and the amount flowing along any path will be inversely proportional to the resistance of that path. A portion of the current, therefore, will leave the rails at points remote from the station and pass through the earth to the adjacent pipes, then flow along the pipes toward the station, leaving the pipes near the station and returning through the earth to the rails and thence to the station as indicated by the arrows in Fig. 1. The region near the station where the pipes are positive to the surrounding earth, and where the current leaves the pipes to return to the rails, is the region where damage by electrolysis will occur, and is called the danger or positive area.

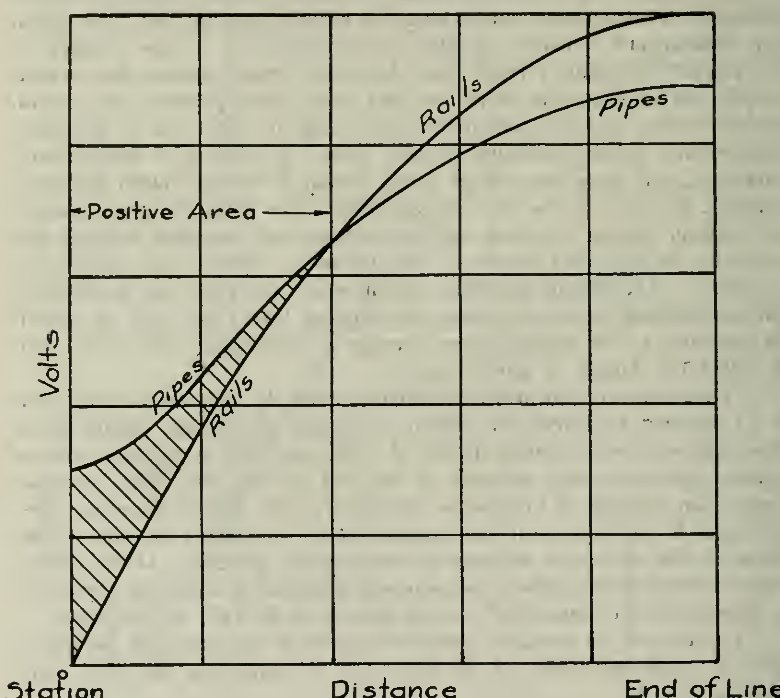
If the cars are uniformly distributed along the line, and if the track is of uniform resistance throughout its length, the voltage profile along the track will be as shown in Fig. 2. This curve is a parabola with a vertical axis and with its apex at the end of the line. The potential drop from the end of the line to any point on the line is therefore proportional to the square of the distance from the end of the line. The slope of this curve is a measure of the potential gradient. If the resistance of the track is known, the potential gradient at any point serves as a measure of the amount of current flowing in the rails at that point.

If there are no metallic connections between the rails and the pipes, then the potential profile of the pipes will be something like that indicated in Fig. 3.

In the regions remote from the supply station the pipes are seen to be negative to the rails and near the station they are positive to the rails. Ordinarily the positive area extends from 30 to 40 per cent. of the distance from the supply station to the end of the line. At the neutral point where no potential difference exists between the pipes and the earth the stray current in the earth and underground structures is a maximum.

The amount of stray current is more nearly a function of the overall voltage drop than of the potential gradient at any point. While high potential gradients extending over a considerable length of track will result in a high overall voltage with correspondingly large stray currents, the existence of a high gradient on a comparatively short section of track is of much less consequence. The reduction of feeding distances and overall potentials has such a marked influence on stray currents that a rather full treatment of this subject is here given.

(c) *Relation of Feeding Distance to Stray Currents and Overall Voltages.* The effects of the reduction of feeding distances on stray currents and overall potential drops are illustrated in Figs. 4 and 5. The stray current curves are calculated from the formulas found in Technologic Paper No. 63 of the Bureau of Standards, entitled "Leakage Cur-



Potential Profile Showing Rails & Pipes Without Connections Between Pipes and Railway Return Circuit

FIG. 3.

rents from Electric Railways." They represent conditions on a typical line having the following characteristics: Double track, 72-lb. rails; length of line, 20,000 feet; calculated resistance of the track, 0.004 ohm per 1,000 feet (this figure allows for a 10 per cent. increase in the resistance of 72-lb. rails, due to the bonds; it corresponds approximately to the resistance of 2.5 million circular mils of copper). The leakage resistance is taken as 0.4 ohm for 1,000 feet of double track, which is a fair average for city tracks in paved streets with a crushed stone foundation. An average load of 40 amperes per 1,000 feet, corresponding to a headway of 4 minutes each way, is considered uniformly distributed

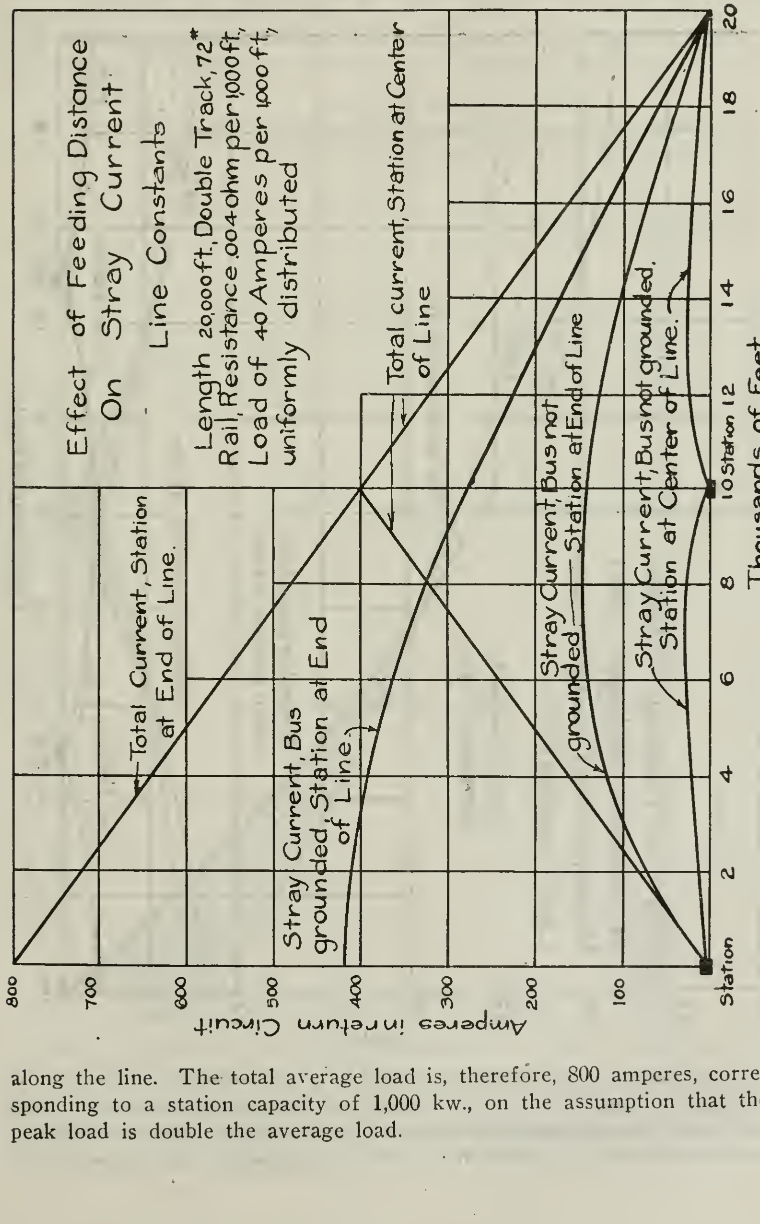


FIG. 4.

along the line. The total average load is, therefore, 800 amperes, corresponding to a station capacity of 1,000 kw., on the assumption that the peak load is double the average load.

Calculations of stray current have been made for both the insulated bus and the grounded bus conditions. This latter occurs only when all of the stray current returns to the negative bus without re-entering the track system, a condition which does not ordinarily occur in practice.

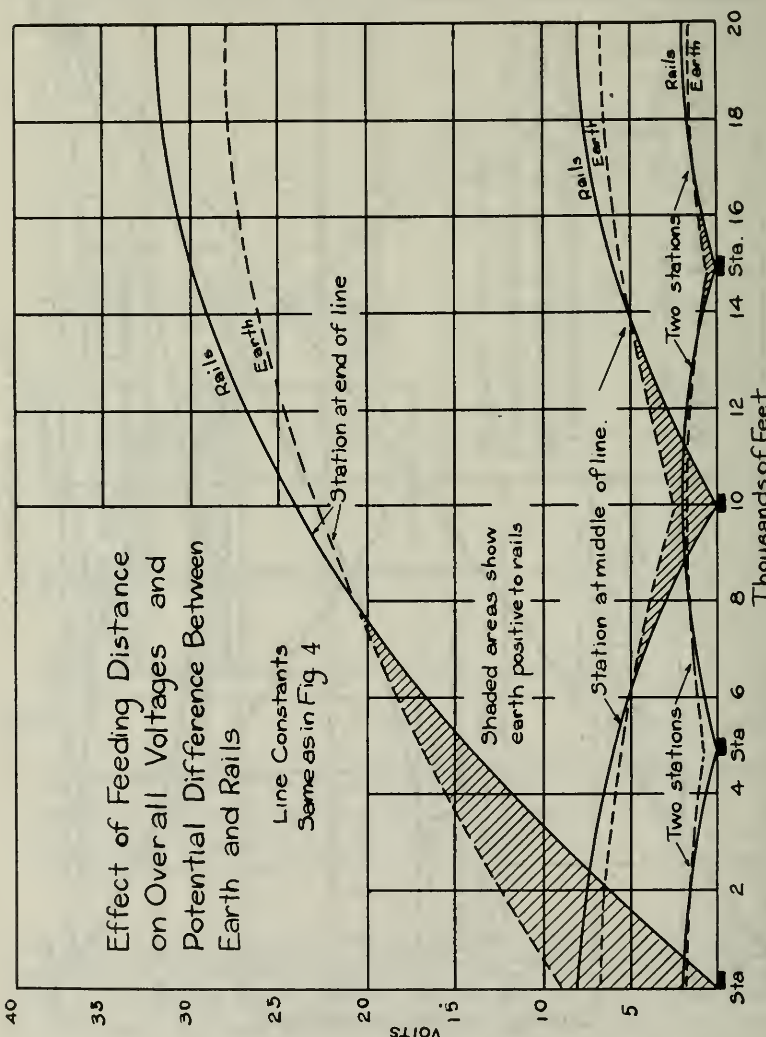


Fig. 5.

An approach to a grounded bus would be a system where extensive pipe drainage existed with a large portion of the current returning to the bus from the underground piping and cable systems. Another condition which simulates a grounded bus is often found where bare copper cables which are used to connect the negative bus with the nearby rails are permitted to come in contact with wet earth or are laid in a stream or river bed. Railway stations generating direct current are often located in low ground or on rivers where condensing water is available and unless special precautions are taken to insulate negative cables entering such stations they are likely to pick up considerable current from the earth, thereby establishing the condition of a semi-grounded bus.

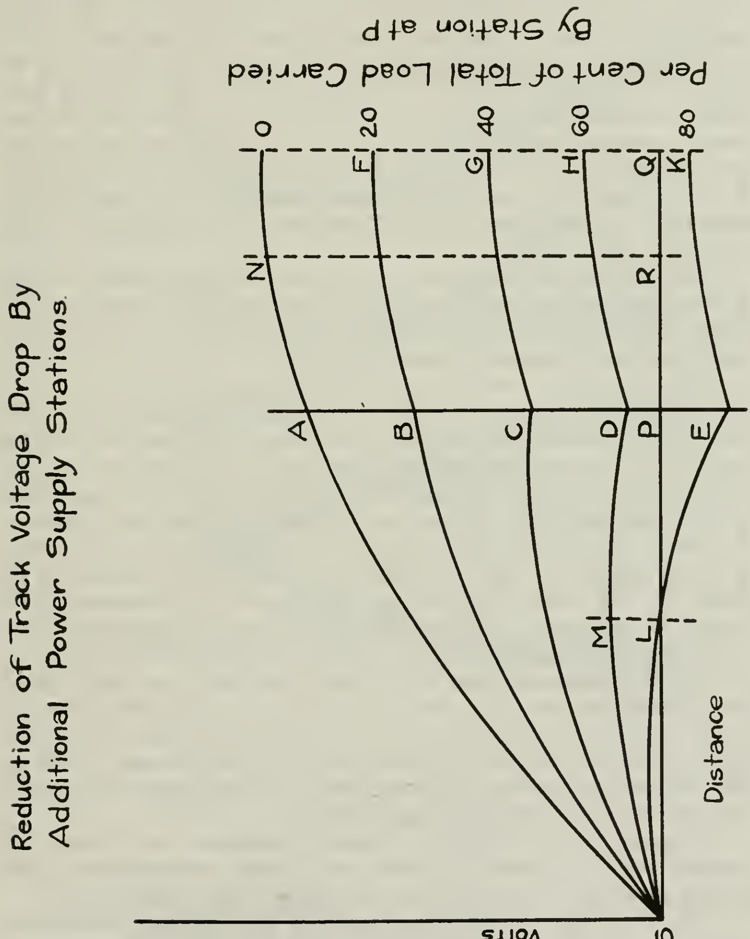


Fig. 6.

Fig. 4 shows the total current returning to a single supply station located at the end of the line. The stray current at any point is also shown for the cases of the bus grounded and the bus not grounded. By insulating the bus the maximum value of the stray current is reduced from 417 amperes to 147 amperes and by putting the supply station at the middle of the line instead of at the end and thereby reducing the feeding distance to one-half, the maximum value of the stray current with insulated bus is reduced from 147 amperes to about 24 amperes.

Fig. 5 shows the overall voltage curves for the same line fed from the end, from the center, and also from two stations located at one-fourth and three-fourths of the distance to the end of the line respectively. Shortening the feeding distance to one-half reduces the overall voltage to one-fourth of the original value and cutting the feeding distance to one-fourth reduces the overall voltage to one-sixteenth of the original value; or as previously stated, the overall voltage varies as the square of the feeding distance. The curves in Fig. 5 are based on theoretical conditions with no stray current. The actual overall voltages would be somewhat less because of part of the current being in the earth. The dotted lines in Fig. 5 illustrate in a general way the potential of the earth and pipes under the several conditions of feeding and the shaded portions represent the areas where the earth and pipes are positive to the rails.

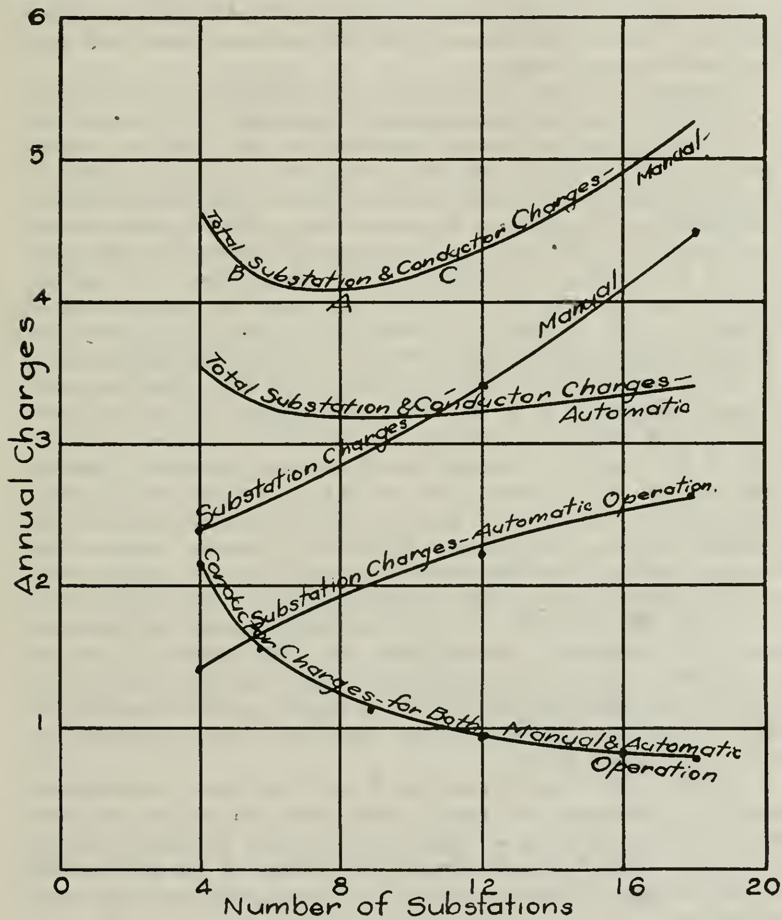
The effect of providing additional centers of power supply can also be illustrated by the curves in Fig. 6, which, while calculated on the assumption of no stray current, illustrate, in a simple case, the effects which have been observed in practice.

The curve SAO represents the track voltage drop on a portion of an electric railway system having a uniformly distributed load. The curve SBF illustrates the condition of a substation located at P, 33 per cent. of the distance from Q to S, carrying 20 per cent. of the total load. In this curve the portion BF is identical with AO. As the load is uniformly distributed, 33 per cent. of the load is on the portion of the line shown by PQ, and of this 33 per cent., 20 per cent. is carried by the substation P. The remainder, or 13 per cent., is carried by the station S. The point B on the curve SBF, therefore, corresponds to the point N on the curve SAO, the distance QR being 13 per cent. of QS.

In the same manner the curves SCG, SDH, and SEK are drawn, showing the conditions when the station P carries 40 per cent., 60 per cent., and 80 per cent., respectively, of the total load. The summit of the curve SMD, in which the station P carries 60 per cent. of the load, is located so that PL equals 60 per cent. minus 33 per cent., or 27 per cent. of the total length SQ to the left of P. The distance QL is, therefore, 60 per cent. of the total length QS.

In general, the conditions are more complicated than those here assumed, and will ordinarily prevent an accurate determination of the relative potentials of the negative buses of the two stations.

(d) *Economic Considerations Involved in Additional Supply Stations.* The practical limit of feeding distances is one that cannot be determined by any general formula designed to fit all conditions. The economic aspects of the problem are far more complex than they appear at first glance and the proper solution involves a careful study of local conditions. However, an increase in the number of power supply stations may be said generally to reduce stray currents to a marked degree and with the advent of automatic control for railway substations the increase in the number of feeding points economically obtainable by this means should result in greatly improved electrolysis conditions.



Relation of Number of Substations to Annual Charges for Interurban Line

FIG. 7.

The number of substations for a given set of conditions may often be materially increased by some additional capital expenditure, but with no increase in annual charges. Also, the original equipment may be distributed to additional stations with little or no capital expenditure, due to saving of feeder copper, and with no increase in annual charges.

The curves in Fig. 7 show the results of calculations on a typical interurban railway system. They are based on the data contained in the paper by H. F. Parshall presented to the (British) Institute of Civil Engineers, Volume 199; and on present day prices of copper and electrical machinery and labor.

Ordinarily in laying out the number of substations for a given electric railway system, the minimum number consistent with economy will be the number selected, such as represented by the curve for manual operation at A. With the growth of traffic the number of stations in operation becomes increasingly inadequate until a condition is reached represented by the point B on the curve, when additional substations are again added. In other words it is customary to operate along the curve from A to B with an insufficient number of substations. It appears, however, that by operating between C and A on the curve instead of between A to B an increase of about 40 per cent. in the number of substations can be made without effect on the total annual charges.

It has been shown on page 40 of this report that when the overall voltage is divided by 4 the amount of stray current will be about one-sixth for the particular conditions discussed. An increase of 40 per cent. in the number of substations will decrease the overall voltage to about one-half of the former value and therefore reduce the stray current to about one-third. It appears, therefore, that by selecting the maximum number of substations consistent with economy instead of the minimum number, the railway companies could reduce to a large extent the stray currents without appreciably affecting their total annual charges and this method should be considered as one of the best possible solutions of the electrolysis problem. The curve for automatic substations is even flatter than that for manually operated stations, indicating that a very large increase in the number of automatic stations beyond the point of maximum economy may be employed without materially increasing the annual charge.

It appears from these curves that if, while the electric railway companies are increasing their power supply, they will at the same time increase the number of power supply stations to the maximum economical number, then they can without any increase in the total annual charges eliminate the greater portion of the stray currents which cause electrolysis.

In many situations the combination of railway substations with light and power substations may offer additional opportunities for economically providing points of supply without additional expense for buildings and attendance.

(e) *Automatic Substations.* During recent years considerable progress has been made in the development of automatic, semi-automatic, and remote control substations for electric railway service.

Automatic stations were first used on interurban lines having infrequent service and the installation usually consisted of a 300 or 500 k.w.

machine. When a car or train of cars approaches one of these interurban substations the voltage of the trolley falls and when it has reached a certain point the substation automatically starts up and carries the load while the train is in its vicinity. As the car recedes from the substation the demand for current decreases and when the load has reached a predetermined minimum the substation shuts down.

This type of substation with small converters has been successfully introduced in some cities, the most notable installation being that at Des Moines, Iowa, where six substations were distributed throughout the city to replace one centrally located power supply station.

The characteristics of large city loads are different from those on interurban lines. The movement of a single car produces but slight fall in the trolley potential and the starting and stopping of the substation is governed by the demand for power during the morning and evening rush hours. A few substations with large converters have been provided for such city service and are now in experimental operation. Remote control substations are also being developed for city service where they are required to operate continuously throughout the load period of the day or during the morning and evening peaks.

Semi-automatic equipment, consisting of re-closing circuit breakers, time switches, and protective devices have been installed in a number of railway substations at a very much smaller cost than would be required for full automatic operation. The circuit breakers in the positive feeders automatically re-close after a definite time interval provided the short circuit or overload has been removed. The synchronous converter has to be started by hand and may be shut down either by a time switch or by hand. Otherwise it operates in a manner similar to those provided with full automatic control.

The first cost of automatic substations is often justified by the saving in operating labor and feeder losses and the recovery of existing feeding copper. Minor savings arise from the elimination of light load losses and the station heating. A further benefit also to be derived from their general use is better voltage conditions and therefore faster car schedules.

The total amount of substation equipment now operated automatically is in excess of 50,000 k.w., and much of the equipment being installed is intended for automatic operation or remote control. The increased savings attending this development will undoubtedly increase the number of substations which can economically be installed on both interurban and city systems, and if full advantage is taken of these economics, the feeding distances will be reduced to such an extent as to greatly reduce stray currents generally.

(f) *Location of Supply Stations.* As pipes and other underground structures become increasingly positive to the earth as they approach street railway supply stations or the low potential points on the track system, it is obvious that if stations were located away from pipe networks trouble from electrolysis would seldom occur. As a rule other considerations will determine the location of supply stations in cities. However, on interurban lines the protection of piping systems in small towns against electrolytic corrosion often presents a grave problem because of the long feeding distances and the difficulty of employing the measures of mitigation ordinarily used in city systems. Under such conditions the location of the supply station at a distance from the city and away from the underground structures may be the most satisfactory way of insuring their protection. This is particularly true of automatic substations which require no regular attendants.

The character of the earth in the vicinity of supply stations naturally has an important effect on the magnitude of stray currents. It is, therefore, desirable to avoid connecting negative feeders to tracks in unusually wet locations.

(g) *Alternating Current Systems.* When the first alternating current railways were proposed, the question of possible electrolytic effects received special investigation. Considerable work was done upon a laboratory scale, in which it was established that alternating currents could produce corrosion on electrodes of the metals commonly used underground, such as lead and iron, but that the effects were very much less in magnitude than those produced by equivalent direct currents, usually less than 1 per cent. and in most cases negligible. See Fig. 16.

The objections to the substitution of alternating current for direct current in the case of systems already installed in large cities are so well known and so serious that the question needs no discussion.

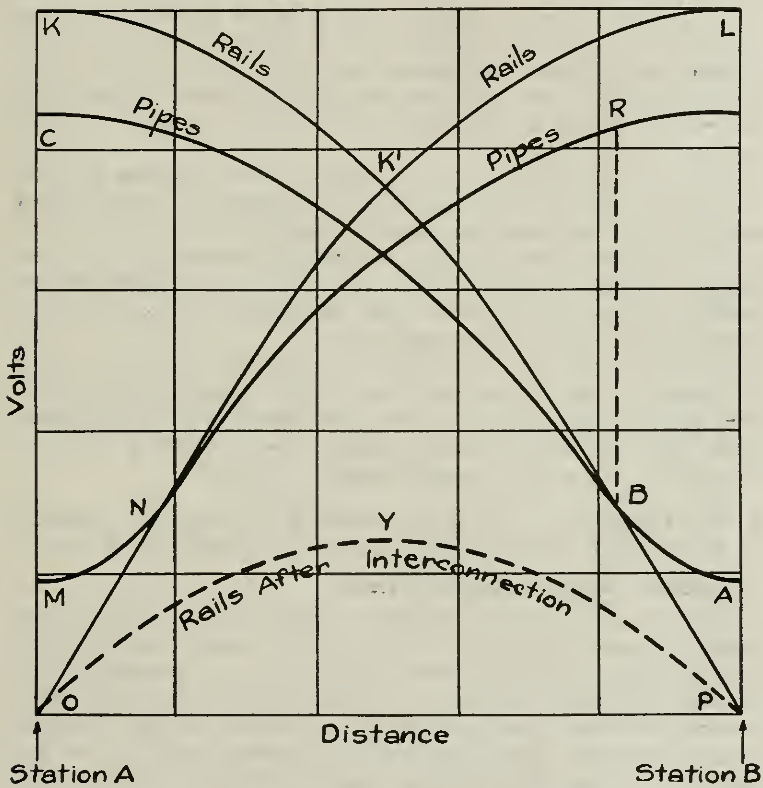
5. Interconnection of Tracks.

Electrical interconnection between parallel tracks in close proximity, or of tracks, one of which passes over the other, belonging to the same or different railway systems is usually a necessity in order to prevent wide fluctuations of voltage between the tracks. Such interconnections tend to equalize the potentials of the tracks so connected and thus tend to prevent the flow of current from the track of high potential through earth and intervening metallic subsurface structures to the track of low potential. In general such interconnections also afford a saving in track losses.

Whether parallel tracks should be connected naturally depends upon the distance between tracks, location of supply stations, leakage characteristics of the roadbeds and other local considerations.

Interconnection generally reduces the track voltage drop by providing more metallic paths for the current. It has also the same general effect as cross-bonding between rails of the same tracks, in that if one track circuit should be accidentally opened the current would be shunted around through the interconnection to the other track. As a rule interconnection of tracks will improve electrolysis conditions but may be detrimental to one locality while improving conditions in another. A failure of one of the companies to maintain its bonding would naturally tend to increase the current on the better bonded track.

Interconnection of tracks has been found to be particularly advantageous where two or more lines of electric railways operating in one locality and belonging to the same or to different systems are supplied from two or more power stations located in different parts of the city. By interconnecting the tracks of such lines in the neighborhood of the power stations and also at several intermediate points a reduction in



Potential Profile
of two Independent Railway Systems
Showing Effect of Interconnection

FIG 8.

the resistance of the return circuit can be brought about whereby the drop formerly existing in one track can be balanced by the drop in the opposite direction in the other track. The rail drop in each track is greatly reduced and all high potential gradients between tracks eliminated.

Where the tracks of the two independent railway systems are parallel and a short distance apart, and fed by power supply stations in opposite directions, the potential profiles of the rails will be as shown in Fig. 8 in which, for simplicity, the negative buses at the two stations have been assumed to be at the same potential. In the figure are also indicated the potential profiles of the pipes adjacent and parallel to the two sets of tracks.

If then gas or water pipes extending from the parallel mains cross under two sets of tracks at different locations where the tracks are at a considerable difference of potential, as at RB, Fig. 8, then the pipes may be negative to one track and positive to the other. At the crossings where the pipes are positive to the tracks electrolysis will be liable to occur.

If now the rails of the two systems are interconnected at points near the two stations and also at intermediate points the potential profile along the rails after such interconnection will be as shown by the curve OYP. It will be noted that this interconnection results in a very considerable reduction of the potential drop in the return circuit, and the resulting reduction in the losses will in many cases be alone sufficient to warrant the cost of the interconnections.

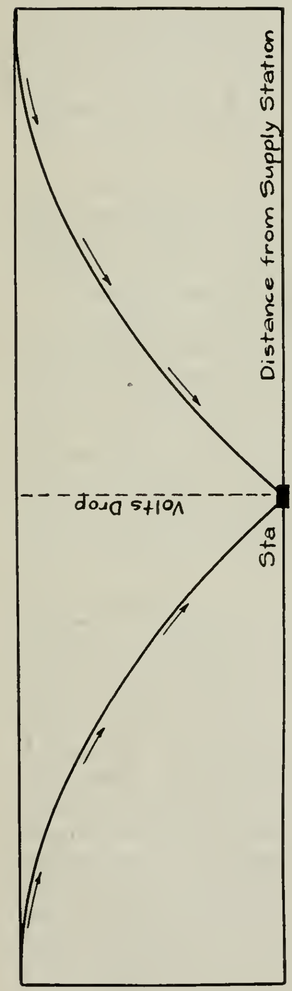
Railway systems employing track circuit signals must insulate their rails used for signal circuits from other systems in order that other currents may not be introduced in the signal circuits and for this reason cannot avail themselves of the advantages of interconnection. This applies only to rails used for signal circuits.

B. FEATURES OF RAILWAY CONSTRUCTION AND OPERATION EMPLOYED FOR ELECTROLYSIS MITGATION

1. Insulated Negative Feeder System.

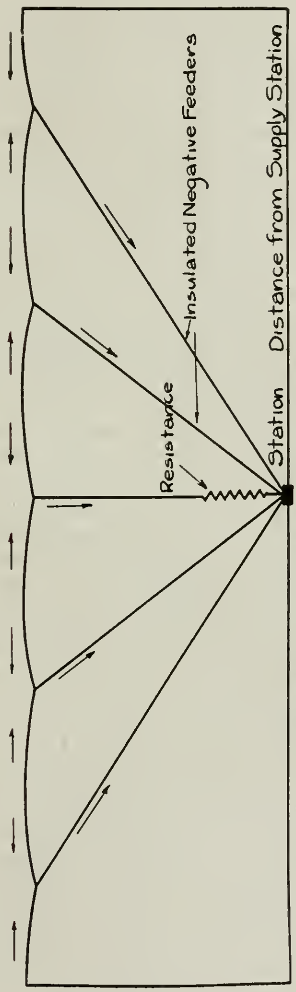
Of the various methods of railway construction and operation employed to improve electrolysis conditions, the insulated negative feeder system has been most widely used. While it has been generally thought that such a system is necessary in connection with a large supply station if underground structures are to receive adequate protection, the present tendency to greatly increase the number of railway supply stations, and particularly the development of the automatic substation, makes the extensive use of insulated negative feeders less important. An increase in the number of track drainage points is often more economically attained by the use of more substations than by the use of insulated negative feeders. The tendency is now in the direction of a relatively few short insulated negative feeders and a large number of substations, rather than an extensive use of insulated feeders from a few large supply stations.

(a) *Description.* In the insulated negative feeder system, instead of tying the tracks directly to the negative bus and depending on the tracks and such copper conductors as may be in parallel with them to return the current to the supply station, the connection at the station is either removed or a suitable resistance is inserted and insulated feeders



Overall Voltage Curves, No Feeders.

FIG 9.



Equi— Potential Insulated Negative Feeder System

FIG 10.

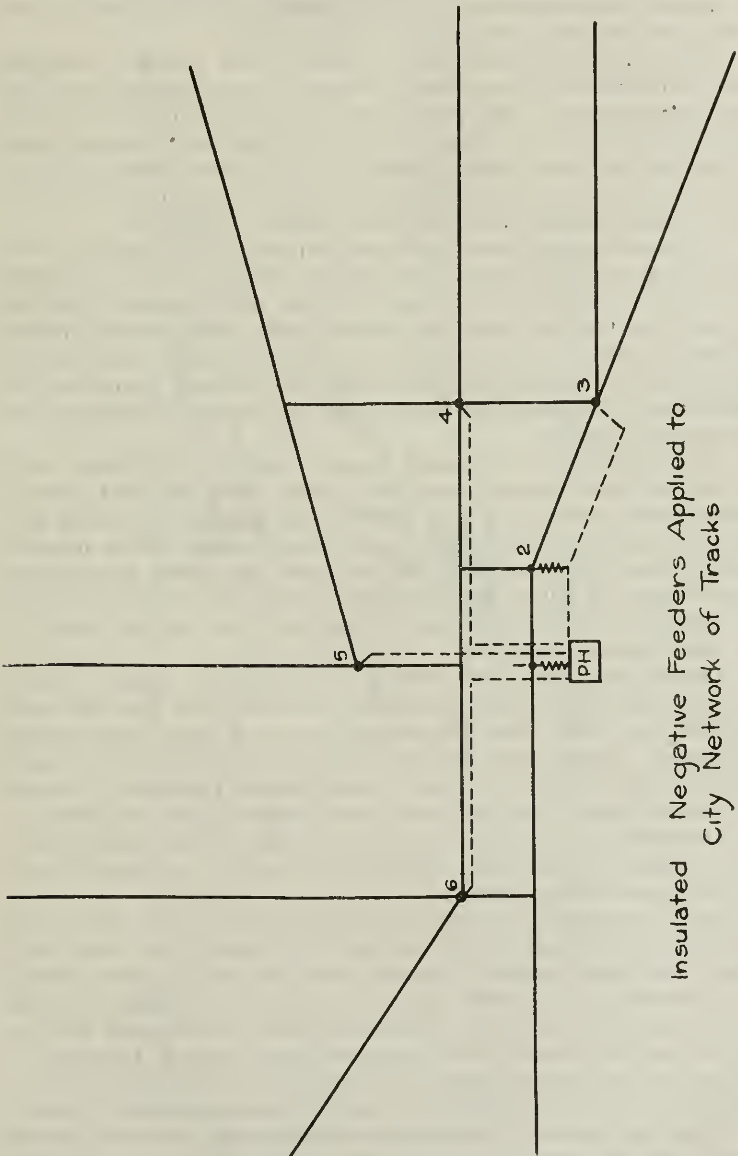
are run from the bus to various points on the track. By thus taking the current from the rails at numerous points, high current densities, and consequently high gradients and overall voltages, can be avoided to any desired degree. As the feeders are entirely insulated from the earth except at points of connection to the tracks, the actual drop in potential in the different feeders is of no importance so far as electrolysis is concerned, so long as the drop is approximately the same in all feeders. It is possible, therefore, to impose any limiting value of overall-track drops and track potential gradients on the track and still be free to design the feeders to give maximum economy which is not possible when the feeders are connected in parallel with the track.

Insulated feeders are sometimes designed for equal potential drops, in which case the several points of connection to the tracks are at the same potential and the system is called an equi-potential or balanced system. When the shorter feeders are designed for a lower drop than the longer feeders, the system is called a graded potential system.

Fig. 9 shows the overall voltage curves representing conditions on a track which is connected directly to the negative bus and with which no additional feeders are employed. The curves are parabolas with the same constants as those in Figs. 2 and 5. Fig. 10 illustrates the same system with insulated negative feeders extended to four points on the track, two in each direction, with a resistor connected to the nearest point on the track. The feeders and resistance are so proportioned that the drop on all is the same under average load conditions and they, therefore, form an equi-potential system. The curved lines represent the potential of the track from point to point, and, as in Fig. 9, the curves are arcs of parabolas.

An equi-potential system of this kind, while it reduces potential differences on the tracks to a minimum and therefore affords the maximum reduction of stray current, usually involves increased energy losses in the return circuit as the rails are merely used as distributing mains for the feeders and are not taken advantage of to return current to the supply station. The equi-potential principle is better adapted to a city network than to a single line, as feeders can be extended to several points on the network at approximately the same distance from the station, and these points can thus be maintained at the same potential. As a rule, however, a gradient is permitted between the points so selected and the track at its nearest approach to the supply station. An arrangement approaching an equi-potential system is shown in Fig. 11, where four feeders are connected to the track at important intersections and connection made to the track near the station through a resistance. One of the feeders is shown connected to the track at two points, a resistance being inserted at the point nearest the station.

This system and also the one illustrated in Fig. 10 are practically equivalent, in the reduction of stray currents, to independent substations at the several points where the current is removed from the track; that is, the results, so far as voltage drop on the tracks is concerned, is the



Insulated Negative Feeders Applied to City Network of Tracks

Fig 11.

same whether a number of stations or an equal number of insulated negative feeders be employed, but the energy losses in both the positive and negative conductors are very much greater with the negative feeder system than with the same number of substations.

Fig. 12 illustrates an insulated negative feeder system so designed that the direction of the current in the rails is not reversed as in the equi-potential system. This graded potential system results in a slightly higher potential at the terminal of each succeeding feeder, starting from the station, and these higher potentials on the longer feeders result in higher overall track potentials than with the equi-potential system, but allow a material saving in copper in the negative conductors.

In designing graded potential feeder systems, it is customary to limit the gradients on the tracks to some definite amount, such, for example, as an average value of 0.5 volt per 1,000 feet and to remove all of the current from the track over an insulated feeder wherever this limiting gradient is reached. By removing no more current at any point than has accumulated up to that point, the current in the track is nowhere reversed and a continuous gradient toward the station is maintained as illustrated in Fig. 12.

(b) *Application of Insulated Negative Feeders.* No definite rules can be laid down regarding when and to what extent insulated negative feeders should be used. In city networks the negative bus should generally be connected to the track at more than one point, that is, negative feeders should be extended along the tracks to nearby intersections. Small stations of 300 to 500 k.w. capacity in city networks may usually be connected directly to the track at one point only and preferably to the nearest track intersection.

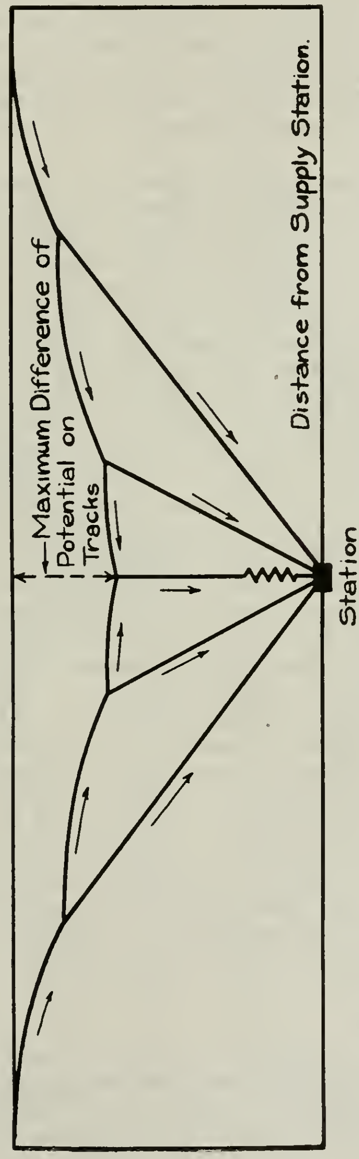
Insulated negative feeders should be run from the negative bus to the rails in such a manner as to insulate them thoroughly from the earth and from each other. The tying together of any of these feeders should be avoided. In some cases, however, it may be allowable to tie a single feeder to the rail at two or more points through resistances to adjust the currents drawn from the tracks at the various points of connection.

Connections to tracks in wet locations make possible excessive current discharge from adjacent underground structures and should therefore be avoided where possible.

Means should be provided on all negative feeders and feeder taps for conveniently measuring the current flow thereon, and where practicable these means should be installed within the railway power station.

Application to Interurban Lines. In the case of a single line, little is to be gained by the use of insulated negative feeders unless they are run considerable distances from the power supply station. For this reason they are not as well adapted to reducing stray currents from interurban lines as from city networks, as the following explanation will show.

It has been shown in the section on Power Supply that stray current results from the action of large overall voltages rather than from high potential gradients. Large overall voltages may be produced either by



Graded Insulated Negative Feeder System

Fig 12.

concentrated city loads over relatively short feeding distances or by comparatively light loads on long lines. The former condition can often be effectively dealt with by the use of insulated feeders because of the short distances involved and a traffic of sufficient density to justify such an expenditure. A very different condition exists on interurban lines where a corresponding reduction in overall voltages would require very long insulated feeders, entailing large expenditures for copper and large power losses.

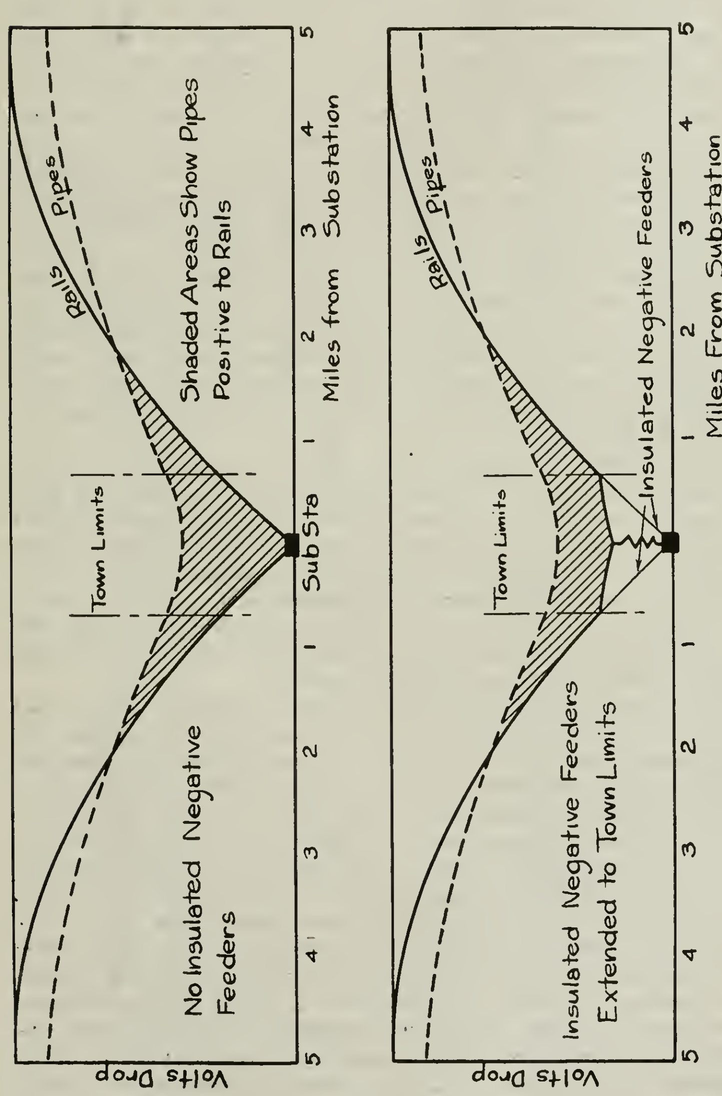
The effect of installing insulated negative feeders within the limits of a small town through which an interurban line passes is illustrated in Fig. 13. Without the use of negative feeders, that part of the piping system within the city limits is shown to be positive to the tracks, a condition which is often found in practice, although not a reliable criterion as to the degree of hazard to underground structures as pipes are sometimes positive to the rails and negative to the adjacent earth. If the potential gradients on the tracks within the city are reduced or eliminated by the use of insulated feeders, the overall voltages are only slightly affected and the potential difference between the pipes and tracks not greatly reduced. In some instances where insulated feeders have been applied on interurban lines, the positive area has actually been extended and no material improvement in the general condition effected.

It is not the intention here to condemn entirely the use of insulated negative feeders for interurban electric lines, because in some cases they have been successfully used. Local conditions vary widely and each problem should, therefore, be worked out on its own merits. However, it can safely be said that this method of electrolysis mitigation is not so well adapted to interurban lines as to city systems.

(c) *Negative Boosters.* Negative boosters are sometimes used in connection with the insulated negative feeder system abroad, but not in this country, so far as known. Unusually long feeders which would have to be very heavy in order to keep the voltage drop comparable with that on the other feeders can be reduced to the minimum size that will carry the current if provided with a booster. When so used, the booster permits a saving in copper but involves an additional energy loss on the conductor. Boosters can also be used to equalize the voltage drops on feeders of different lengths. They have proved economical under certain conditions and uneconomical under others. In general it is simply a question of the fixed charges on copper as against the fixed charges and operating cost of machines.

2. Three-Wire System.

(a) *Description.* This method of power distribution is similar to that commonly used for city light and power, and known as the Edison three-wire system. It may take two different forms which are the same in principle, but which differ radically in the arrangement of the feeder system. One of these, known as the parallel three-wire system, is directly analogous to the ordinary three-wire power and lighting system. The typical arrangement for the case of a double-track line



Insulated Negative Feeders Applied to Interurban Line

Fig 13.

using this system is shown in Fig. 14. Here one trolley is negative and the other positive, the tracks being the neutral conductor. This results in a potential difference between trolley wires equal to twice the operating voltage at points of connection between the trolley sections. It is evident that only the difference in the load on the two sides of the line returns to the powerhouse on the track, although there may at times be heavy circulating currents flowing between cars in short sections of track. If the cars run at frequent intervals, however, such circulating currents will not have to flow over sufficiently great distances in the tracks to cause nearly as large track drops as would occur with the same loads under two-wire operation. The result would be that where load conditions are reasonably favorable for the three-wire system, large reductions in potential drops in the negative return could be secured.

While almost perfect electrolysis conditions could be obtained with the parallel three-wire system, the difficulty of properly insulating the two trolley wires from each other, especially at crossings and switches, has been considered so great that the sectionalized three-wire system is considered the more practicable and has therefore been employed in all installations which have come to our attention. It is shown diagrammatically in Fig. 15.

In this form the feeding district is divided into sections, and alternate sections are supplied by feeders running from the positive bus, while the remaining sections are supplied by feeders from the negative bus, the difference of potential between the two buses being approximately 1,200 volts. In this way, the existence on the same portion of the street of two trolleys having a high difference of potential between them is avoided. The tracks, as before, serve as the neutral conductor and convey the current from the cars in one section to those in the adjoining section and return the unbalanced current to the powerhouse.

(b) *Insulation of Trolley Sections.* The problem of insulating the positive and negative trolley sections from each other is one that will require considerable care. At points of simple juncture this has been accomplished in some cities by the use of two standard 600-volt trolley section insulators in series, with a dead section of trolley wire from 4 to 6 feet in length between them. In other cities the two section insulators are brought together, thereby simplifying the overhead construction. It is also possible to use a single 1,200-volt section insulator 18 to 24 inches long. Where trolley wires of opposite polarity cross, it will probably be found better to make the entire intersection of one polarity rather than try to insulate the crossings. At the intersection of two double-track lines this will mean the installation of four double section insulators as just described. Where such changes are made, the more important of the two lines should be made the continuous one to avoid interruption of service due to failure of power on the other line. Warning signs should be hung on the span wire at all section insulators and motormen should be instructed to coast across these points.

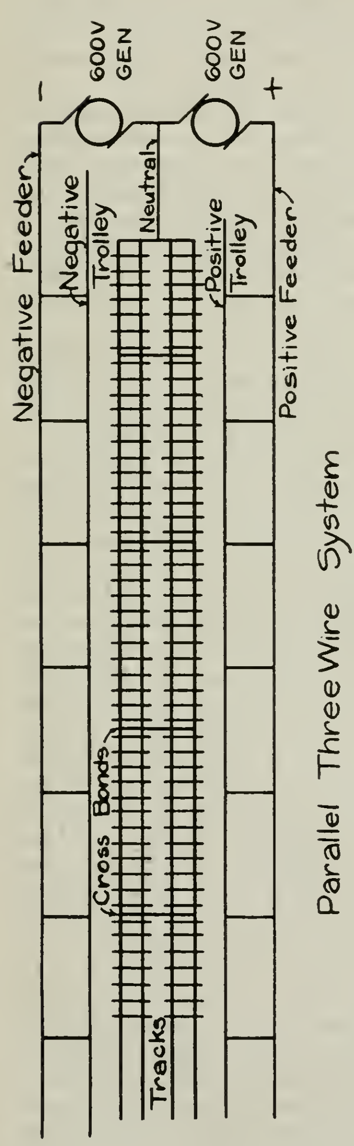

600V GEN
600V GEN
−
+
Negative Feeder
Negative Trolley
Neutral
Positive Trolley
Positive Feeder
Cross Bonds
Tracks
Parallel Three Wire System

FIG. 14.

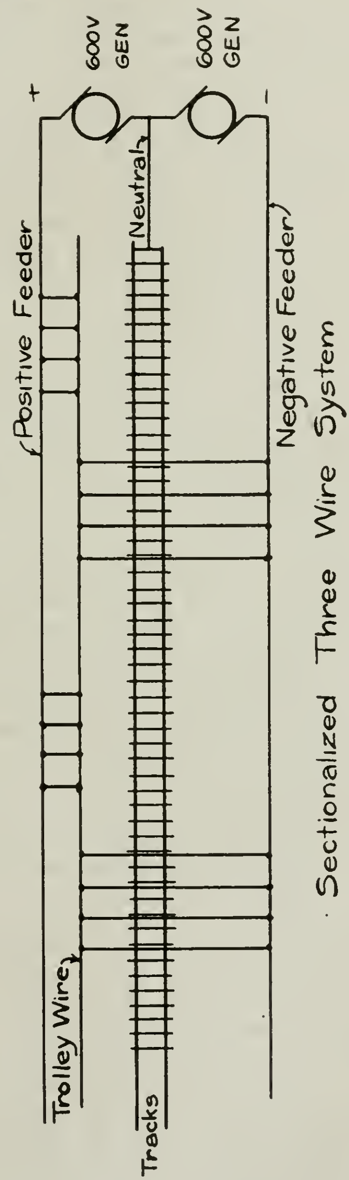

600V GEN
600V GEN
+
−
Positive Feeder
Neutral
Negative Feeder
Trolley Wire
Tracks
Sectionalized Three Wire System

FIG. 15.

(c) *Costs.* The principal economy resulting from the installation of the three-wire system is the saving in track losses, which are greatly reduced, although not entirely eliminated, while there usually will be increased station losses due to the necessity of always operating two sets of generators or converters.

In systems having a relatively small number of multiple unit power supply stations, the cost of converting a system for three-wire operation is usually, but not always, smaller than the first cost of insulated negative feeders, or any other measure that will give the same degree of protection from electrolysis. The available data on three-wire systems, both as to costs and effects of electrolysis conditions, are not sufficient to warrant the laying down of general rules as to the extent of its application. The local factors involved in each case are often peculiar and require special consideration.

In cities where uninsulated negative copper has been installed, it may be reclaimed after conversion to three-wire operation, unless it has been installed under pavement or embedded in concrete, and the salvaged copper may largely, if not entirely, cover the cost of conversion.

It is good practice to provide an additional bus in the supply station for the generators and feeders operated with reverse polarity. Double throw switches are also installed for these feeders and generators.

(d) *Difficulties and Limitations.* One difficulty which sometimes will be encountered in three-wire operation is that of reduced station capacity, as two or more machines operating in parallel will have a much greater capacity at times of excessive demand than when divided on two independent circuits. Heavy interurban trains, particularly when starting, often demand the full capacity of a supply station and the same condition exists at times of unusual loads, such as occur after a tie-up or following a ball game or circus. Where the generating capacity of both the positive and negative sides of the system is large in comparison to the maximum demand of any trolley section, this objection does not exist, but where only a single small machine is available for one side of the load, considerable difficulty may be encountered in taking care of the peak demands under extreme conditions. Where necessary these extreme peak demands can be taken care of by operating all of the machines on one polarity during this period. Double throw switches, by which this can quickly and conveniently be accomplished, are usually provided with three-wire operation.

One instance of an overload with three-wire operation resulted in the too frequent blowing of the circuit breaker on the negative generator. This was eventually overcome by installing a series resistance which is automatically cut into the circuit when the current reaches a predetermined maximum value, thereby limiting the current to a fixed amount. The equipment used for this purpose is identical with that employed for automatic railway substation control.

Not only are unusual loads of short duration difficult to take care of with three-wire operation, but where the entire capacity of a station with all machines in parallel is required to carry the normal peak-load, it may be impractical to convert for three-wire operation. In general, it will, of course, be difficult to divide the positive and negative loads in the same ratio as the capacities of the two groups of generators assigned to them. Moreover, the load factor of the whole system is always greater than that of any part, and the generators when divided into groups will therefore be operating at poorer load factors and consequently at lower efficiencies than when in parallel. Therefore, where no excess generator capacity exists, it may sometimes be necessary to install an additional unit in converting a system for three-wire operation.

Owing to the continual movement of cars from one trolley section to another of opposite polarity, there is a considerable variation in the track potential at any point. This is particularly true on lightly loaded lines and results in wide fluctuations, and even reversals, between the tracks and adjacent underground structures. While the algebraic average values of such potential differences may be greatly reduced by the adoption of a three-wire system, a continuously negative condition of underground structures cannot ordinarily be expected.

Other difficulties of less importance have been suggested: (1) Some equipment, such, for example, as arc-headlights, ampere-hour-meters and auxiliary battery control, requires a single polarity for its successful operation. Where such equipment is used it will be necessary to provide reversing switches. (2) Two trolley poles in parallel cannot be employed on a single car or on trains as they would bridge trolley sections of opposite polarity when moving across section breakers. (3) A negative trolley would change the character of the electric arc used on tracks for arc-welding and building up joints and in some operations might be objectionable. (4) Commercial customers receiving power from trolley feeders may, in some cases, be inconvenienced by a change of polarity.

(e) *Practicability.* None of the difficulties here cited can be considered of insurmountable character, and like many other things, the system can be made to work satisfactorily if the necessary attention is given to it. Experience has fully demonstrated that it will greatly improve electrolysis conditions when properly applied and also give better operating voltage at the cars. However, to secure the best possible results with this system, it will often be necessary to change feeder copper and shift section insulators to obtain the desired sectionalization.

(f) *Extent of Adoption.* Until recent years the three-wire system has not been employed for street railway work in this country, although it has been in use in Brisbane, Australia, and Nuremberg, Germany, for a number of years. In the last few years it has received some attention in America and is now in operation in Omaha, Wilmington, Winnipeg, Canada, and in some portions of Los Angeles and Milwaukee.

The Los Angeles installation has been in operation since 1915 and more recently has been extended to include several additional station districts. In Omaha a trial installation in one station district was made early in 1917. After several months' trial with the experimental installation, the main station district was converted for three-wire operation and has since been so operated.

Three-wire operation was adopted in Winnipeg as a means of meeting the requirements of a law passed by the Manitoba Legislature, prescribing certain limitations in track voltage drops. Two substation districts were changed over in 1919, and since that time practically the entire system has been converted to three-wire operation.

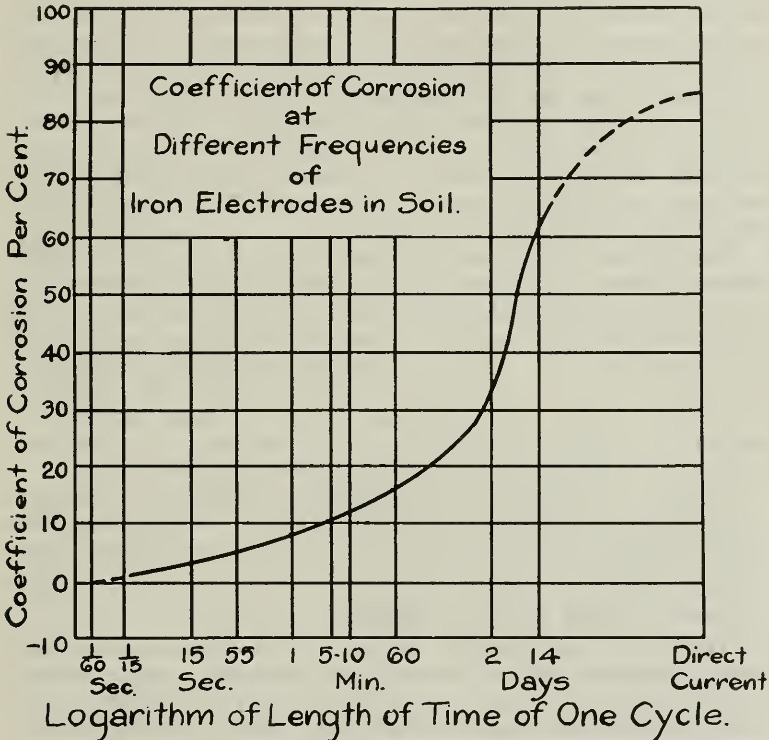
In 1920, after considerable experimenting, a three-wire system was substantially completed in Wilmington, Delaware, and a complete electrolysis survey made under both two-wire and three-wire operation. With the latter, a considerable improvement in car operation due to higher average voltage was reported, and also better electrolysis conditions on water and gas pipes. Stray currents and overall potentials were reduced to about one-half their values with two-wire operation. Reversing potentials were found on the telephone cables in some areas and some adjustment of the drainage of this system will be necessary before it can be said to be entirely satisfactory.

3. Reversed Polarity Trolley System.

This method of railway operation involves using the running tracks as the positive conductor instead of the trolley wire. It has at various times been suggested as a means of electrolysis mitigation, and in at least one case it has received an extended trial. Fundamentally, however, it is not a mitigation method, because it merely reverses the direction of the stray current and in no way affects the magnitude thereof. With reversed polarity the same amount of corrosion will result as with normal operation and the only difference will be the localities in which the damage will occur. Under normal operation using the running tracks as the negative conductor, the electrolytic damage will generally be confined to the area immediately surrounding the direct current power station or the track feeder connection points. With reversed polarity, the electrolytic corrosion will be scattered over the outlying districts which with normal polarity would constitute a negative area. If the trolley system is operated with reversed polarity, it is extremely difficult to effectively drain the lead sheaths of underground cable systems, because there is no definite point of low potential to which to drain.

In 1912 the polarity of the electric street railway system in New Haven, Connecticut, was reversed, making the running tracks the positive conductor. This method of operation was adopted by the railway company in order to afford immediate relief to the gas works, and to the water and gas piping systems in the central part of New Haven, where very serious damage was occurring. It was then thought that in the outlying sections the damage would be less concentrated, and also failures would be less serious and more easily repaired, than in the central business district. It soon became evident that it was practically impossible to adequately drain the underground telephone cable system, and that even with reversed polarity the general electrolysis conditions of the water and gas piping systems were still far from satisfactory, and after a trial of eight years, this method of operation was abandoned.

The New Haven experiment, therefore, indicates that the reversal of railway polarity to rails positive is merely a means of relieving dangerous electrolysis conditions in the vicinity of the power station, at the expense of the cable and piping systems at some distance from the sta-



Variation of Coefficient of Corrosion of Iron with Frequency

Fig 16.

tion. When no underground cable systems are involved, reversed polarity is useful as a temporary means of immediate relief to an endangered piping system in the interval immediately preceding the installation of effective electrolysis mitigation.

4. Periodic Reversal of Trolley Polarity.

If the polarity of the trolley is reversed daily, at a time when the load on the system is a minimum, few operating difficulties will be encountered and some improvements in electrolysis conditions will result. It is obvious that pipes in any locality will be in a positive condition only half as long as with normal operation, and there may also be a further reduction of electrolysis due to redeposition of the corroded metal during the period when the pipes are negative. Laboratory experiments made by the Bureau of Standards, the results of which are shown in Fig. 16, indicate that with a daily reversal of polarity, the corrosion of iron pipes at any point will be about twenty-five per cent. as great as will result without such reversals. A similar relation, though not precisely the same as that shown in Fig. 16, exists with respect to lead when subjected to periodically reversed currents.

This method of operation has been employed by the Pacific Electric Railroad Company of Los Angeles since 1918 in Pomona, Redlands, San Bernardino, Riverside, and Corona. In general it is not applicable to cities where lead cable systems are installed underground, as it would greatly complicate and sometimes render impracticable the drainage of such systems. However, where the cable system is small and confined to the vicinity of the power supply station it may be drained satisfactorily through an automatic switch which permits current to flow from the cables, but automatically prevents the reversal of such flow.

Some of the operating difficulties discussed in connection with three-wire systems will be encountered with this system. The operating difficulties attending a more frequent reversal of the trolley potential would be considerably greater, and no attempt so far has been made to do this.

5. Double Contact Conductor Systems.

The double overhead trolley system of electric traction as at present used in Cincinnati, and the corresponding underground conduit systems as used in Washington and in parts of New York City, if properly maintained, eliminate the danger of electrolysis. This system has in past years been strongly urged by some pipe owning companies and engineers who believed it to be the only method by which complete immunity from electrolysis could be obtained. It is now generally recognized, however, that a substantial degree of protection can be obtained by less expensive and objectionable methods and the demand for the double contact conductor system is, therefore, not being pressed at the present time. The chief objections to its use are the cost of installation and the increased operating difficulties which it involves, as well as an unsightly appearance of the streets in the case of the double overhead trolley. The double contact underground system, as used in New York and Washington, not only removes the source of stray current, but requires no overhead wiring or poles and in rare cases may be justified or required for that reason alone. Merely as a means of electrolysis mitigation, the increased cost of the double contact conductor system does not appear to be justified.

II. UNDERGROUND STRUCTURES SUBJECT TO INJURY BY STRAY CURRENTS

A. LOCATION WITH RESPECT TO TRACKS

In general, the problem of protection from stray currents has to do with conditions under which the affected structures and the tracks are already in place, that is, where their respective locations are fixed. In the great majority of instances, therefore, a discussion of the most favorable relative location of underground structures and rails can have but little more than an academic interest. However, in laying new underground structures or replacing old ones, it is in the interest of safety to locate them at as great a distance from the rails as possible. Uusually conditions other than electrolysis determine the location of mains, but where it is possible to locate mains on both sides of a street having car tracks, such construction prevents the crossing of service pipes under tracks and is in the interest of good electrolysis conditions. Where mains or services must cross under tracks there is a considerable advantage in having them as deep as possible, but a depth of more than 4 or 5 feet is ordinarily not justified.

B. CABLE SYSTEMS

1. Avoidance of Accidental Contacts with Other Structures.

From an electrolysis standpoint, it is usually necessary to treat lead sheath cables as distinct from other underground structures due to the fact that lead is appreciably more susceptible to corrosion from stray current than iron, and also because different measures are usually applied to the protection of lead sheath cables than to other underground metallic structures. One ampere flowing steadily for a year will carry into solution about 20 pounds of iron or about 74 pounds of lead. This high electro-chemical equivalent of lead and the thin walls ordinarily used for cable sheaths require that unusual care be exercised in their protection.

In the Bell Telephone System precautions are taken to avoid contact between its lead sheathed cables and other underground structures, such as foreign cables, rails, steel bridges, gas or water piping system and the metallic structure of steel-frame buildings. Where it is necessary that cables cross a bridge structure, this is frequently accomplished in creosoted wood duct. Occasionally, however, iron pipes are used to conduct cables across a steel bridge, but where this is done, these pipes are supported so that they are insulated from the metal work of the bridge.

2. Conduit Construction.

Cable sheaths cannot be said to be insulated from earth even when installed in non-conducting duct material, but as compared with pipes which are laid directly in the earth, their resistance to ground is generally very high. Unless surrounded with mud or water, cable sheaths usually make a line contact with the duct walls, whereas pipes make a surface contact of much greater area.

The study of the insulation of cable sheaths from earth therefore resolves itself into a study of suitable conduit construction methods since experience has demonstrated the failure of any sort of wrappings, dips, or coatings to afford protection of any value from electrolysis. Indeed, wrappings, dips, and coatings have been shown to be distinctly harmful where pipes or cables are positive to the earth since they tend to localize the discharge of current and thus to accelerate failures.

(a) *Signal Cables.* The experience of the Bell Telephone System has demonstrated that multiple and single vitrified clay duct and creosoted wood duct are all equally good as duct material from the standpoint of electrolysis, their choice in specific cases being a question of supply and cost. Iron pipe is occasionally used, but, due to its cost, only when necessary in avoiding obstructions.

When iron pipe is used, it is so laid that there will be no contact between it and the trolley rails, steel bridges, water pipes, gas pipes or other underground structures or the metal work of buildings. When iron pipes must be laid as conduit so close to rails or other grounded metallic structures that a separation of at least one foot of earth cannot be obtained, the pipes are separated from the rails or other grounded metallic structures by a layer of concrete or creosoted plank. Three inch vitrified sewer tile with cement joints is now being commonly used for laterals to poles or building connections.

In good conduit construction the necessity is recognized of rendering the joints between lengths of duct material, sufficiently tight to prevent the infiltration of dirt and silt and also to maintain a sufficient slope to the conduit to insure good drainage toward manholes, the manholes in turn being drained by sewer connections or to sumps. Particular care is exercised to prevent dips or pockets in conduit runs where moisture might collect. It is the practice to rack cables in manholes, a free space of twelve inches being maintained between the lowest cable and the manhole floor. The cables are in metallic contact with the metal hanger which, in turn, may be in contact with or built into the manhole wall, experience having indicated that no appreciable increase in cable resistance to earth is obtained by insulating the cables at these points with porcelain or other insulating material.

Where lateral cables enter buildings, it is the usual practice in the Bell System to avoid all contact between the cable and the metal structures of buildings, and wherever this is impracticable, the continuity of sheaths on the entering cables is broken by an insulating joint.

Occasionally conduit runs must be built through swampy ground or along sections of the coast where the conduit is permanently below sea level. Where such conditions are encountered, no method is practically possible for insulating cable sheaths from earth and such insulation is not attempted. Such locations are frequently extremely troublesome from the electrolysis standpoint, and therefore special precautions have to be taken.

(b) *Power Cables.* The practice in conduit construction for light and power cables is somewhat different from that used for signal cables because the former are characterized by necessity of providing for troubles originating within the cables and for the dissipation of the heat losses of the cable. The most common types of duct material used are single duct vitrified tile, multiple duct vitrified tile, fibre conduit and stone conduit. Iron pipe is frequently used for short laterals to buildings and for cable pole connections, and occasionally where on account of lack of space other types cannot be installed. It is a common practice to install a 3-inch concrete envelope entirely surrounding all types of power conduits. Multiple conduit made up of single duct tile is laid with staggered joints and in the case of the fibre and stone conduit, the ducts are separated by an inch or more of concrete. Fibre duct is generally considered as a mold for the concrete, which latter is depended upon for strength and for the separation of the cables in the several ducts.

The waterproofing of underground conduits for the purpose of excluding moisture and improving the conditions regarding electrolysis was tried a number of years ago, but it was very expensive and found to be quite useless unless the manholes also could be waterproofed, and this did not appear to be practicable.

The reports of the effect of the different types of duct on electrolysis conditions vary considerably, but this is probably due to the nature of the soil in which the conduits are located, the amount of moisture in the soil and the character of the paving under which the conduits are installed. In those locations where the conduit is located in flat country with poor drainage and with the natural water level only slightly below the level of the conduits, the effect of the dirt and moisture in the ducts and the dampness in the surrounding earth is to lower the resistance of the cables to earth so that this value is not materially greater than it would be if they were installed directly in the earth. In other locations where the surface of the ground is hilly or sufficiently undulating to afford good drainage facilities, the cables installed in ducts with a concrete envelope are fairly well insulated from the earth.

Although iron pipe is not generally used in line conduits, it is frequently necessary to employ it for laterals from manholes to poles and buildings, in order to avoid obstructions or to comply with requirements. If used as conduits for drained cable systems, iron laterals will increase the danger to gas and water service pipes which they cross. They also lower the resistance between the earth and cable sheaths which they contain and thereby enable the cables to pick up larger amounts of stray current than they otherwise would.

In order to afford the return current a metallic path to the station in case of the failure of the cable, it is the standard practice with many companies to connect the lead sheaths of all of their cables in every manhole. This serves also to prevent serious differences in potential between the lead sheaths of cables in the same conduit at the time of a burnout and the resulting damage to lead sheaths in adjacent ducts which would otherwise occur.

Where metal cable racks are used in manholes it is a frequent practice to insulate the cables from such racks, this being done to prevent damage from electrolysis as well as to prevent damage in case of a burnout of one of the adjacent cables.

Unless necessary as a protective measure for isolated sections, cable sheaths should not be artificially grounded. Grounds in negative areas through which stray current might be picked up should be avoided wherever practicable.

3. Surface Insulation.

In the early days of the use of lead-covered cables for light and power in this country, it was customary to have the lead covered cables incased in a wrapping of jute saturated with a preservative compound with the idea of preventing damage to the cables by electrolysis. While this may have been fairly satisfactory as a temporary expedient, the preservative compound in the course of time would gradually disappear and the rotting of the jute would follow. In pulling such cables out of the ducts, it was found in some cases that the jute was so badly rotted that it could not be left on the cables when they were reinstalled in another location, and in other cases, the jute would adhere to the ducts or become caught on the edges of the ducts and form a very serious obstacle to the removal of the cable. Moreover, coatings of this character are not always a protection against electrolysis and may even accelerate it by localizing the corrosion, as explained in the discussion of surface insulation for pipes. On account of these difficulties, the use of the jute covering on the lead covered underground cables was generally abandoned some years ago.

4. Insulating Joints.

Some light and power companies have used insulating joints for protecting their cables from electrolysis. In some cases each section was connected to a ground pipe or plate under the floor of the manhole. If the conditions were favorable for electrolytic action, these ground plates or pipes served merely as auxiliary anodes and would be destroyed by electrolytic action in the course of a few years, thus rendering them ineffective except at a considerable annual expense for maintenance. Partly for this reason, but more because of the general adoption of cable drainage as a method of electrolysis mitigation, the use of insulating joints for protecting lead covered cables for light and power purposes has been practically abandoned in this country.

As the drainage of cables requires continuous lead sheaths, insulating joints are not now ordinarily used in cable systems. With drainage it is also desirable that the several cables in any duct system be bonded together in the manholes so that all cables may be equally drained and also that in case of a failure of one cable the current through the fault to the sheath can find a continuous metallic return path to the station. If the insulation fails on a cable with an isolated lead sheath, the potential of the sheath will become approximately that of the conductor and destructive arcing may occur at the insulating joints, and in addition, holes will be burned in the lead sheaths of the cable where it is in accidental contact with other cables or where it rests on metal cable racks or supports in manholes. Where insulating joints are used, it is therefore quite necessary to ground each section of the sheath.

Under special conditions insulating joints can sometimes be used to advantage in protecting cables from electrolysis, as for example, when the cables are remote from any railway tracks or negative return circuit to which they can be drained, or where a cable system which is not drained can be prevented from collecting stray current at points of intersection with railway tracks by their use. Fig. 17 shows the type of insulating joint used by several large electric power companies in the sheaths of transmission cables which are not protected by drainage.

Another situation sometimes requiring insulating joints in order to prevent cables from picking up excessive current, or to prevent arcing, is to be found where they make contact with a steel bridge or are otherwise brought into intimate contact with the earth. Under such conditions the section making contact can be isolated by the use of insulating joints and continuity of the system maintained by bonding around the section so isolated. Such conditions as these, however, are comparatively rare.

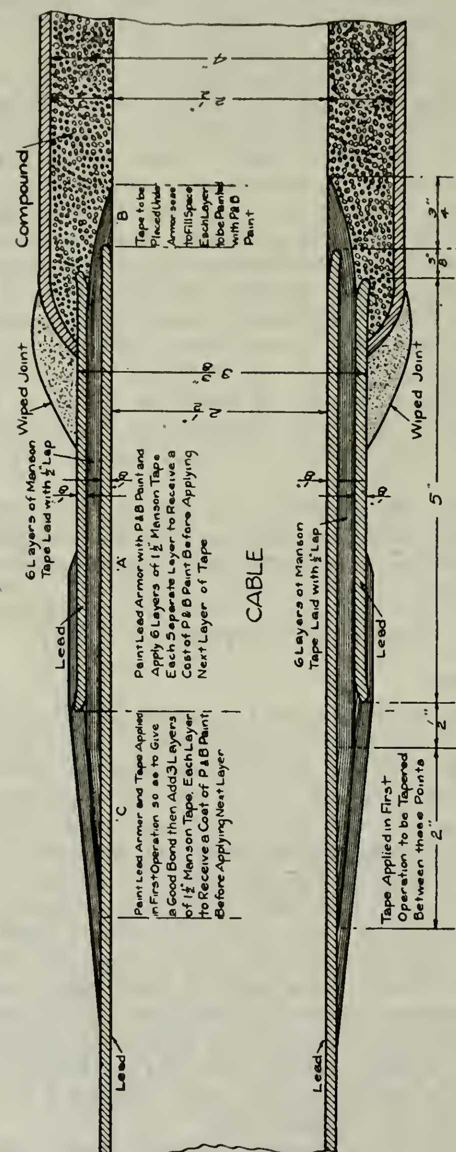
Insulating joints in lead sheaths are not only expensive but represent points of discontinuity which may give rise to various troubles and are usually avoided in practice except under such unusual conditions as are here mentioned.

C. PIPE SYSTEMS

1. Surface Insulation.

In the cities where there is trouble from electrolysis, the service pipes of the gas and water companies are more subject to failure than the cast iron mains as the walls of the wrought iron pipes are much thinner. Also, in the electrolytic corrosion of cast iron pipe a graphitic residue remains intact and has a strength sufficient to withstand gas pressure and in some cases even low water pressure, while with wrought iron or steel the metal is corroded away without leaving such a residue. For these reasons some gas companies have made it a practice to apply a surface covering to their service pipes. This covering is generally similar to that described above for lead covered cables, but it sometimes consists of several layers of jute, burlap, cheese cloth, or paper, each of which has an application of insulating preservative compound before applying the next layer. Such insulating coverings have been more successfully applied to services than to lead covered cables. The expense of this covering usually precludes its use for cast iron mains, although it is sometimes applied to wrought iron or steel gas mains.

The principal difficulty in coatings applied to pipes or lead cable sheaths is that the coatings are not continuous and that in spite of all efforts for their prevention minute holes or pores will exist in such coatings. Through these minute pores the electrolyte will ultimately pene-



Cross Section of Insulating Joint for Power Cable Sheaths

FIG. 17.

trate and electrolytic action will result. As the amount of pipe or cable surface exposed through these pores is small, the action will be very slow at the start and it may be quite imperceptible for a number of months. In the course of time, however, if the conditions are favorable for electrolysis, an oxide of the metal will be formed opposite the pores and as the oxide occupies more space than the metal, the coating will be lifted from the metal, thus rapidly increasing the area of metal exposed to the electrolytic action. As this action is concentrated at a comparatively few points by the coating, the result is that the destruction of the pipe or cable may occur more rapidly, due to this intensified local action, than would occur if the pipe or cable was without such coatings so that the action would be distributed over the entire area of pipe or cable.

Surface insulation for the protection of pipes and cables against soil or salt water corrosion is often effective, but as described above, these coatings gradually deteriorate when subjected to any appreciable potential difference.

Thick coatings in the form of pitch or parolite poured into a containing box built around the pipe, have been used successfully in special cases. The box should be quite strong so as not to sag beneath the weight of the insulating material while pouring or after back-filling. The pipe should be supported in this box by means of blocks of glass or of pitch impregnated wood, so as to prevent its exposure in the event of the cold-flow of the insulating material. In pouring, extreme care must be exercised to prevent particles of earth or stone from getting into the box, and the insulating material should be hot enough to flow freely without boiling or bubbling. If it is too hot, the boiling or bubbling will result in air holes when the material solidifies, and these air holes may admit moisture to the pipe. If the pipe to be covered is laid on a grade, or if it is more than 25 feet long, it will be necessary to pour the material in sections, using dams made of pitch impregnated wood to retain the molten material. The material should cover the pipe to a depth of about two inches and a rigid cover should be placed on top of the box or trough to prevent stones or earth from working their way through the insulating material. This boxing method is also applicable to service or other small pipes, and while somewhat more expensive, it is preferable to the wrapping method because in its application there are fewer chances of imperfections escaping detection.

Too much care cannot be exercised in applying insulating coverings in regions where there is a strong tendency for current to leave the pipe. A single imperfection through which moisture can reach the pipe will cause it to be destroyed more rapidly with the covering than without it. As an additional precaution where insulating covering is applied in a positive area, insulating joints are often installed in the pipe at each end of the covering. If the covered section is more than 2,000 feet long, additional insulating joints should be installed at intermediate points.

The application of insulating covering is not always limited to the positive areas in which current tends to leave the pipe. They are quite often used to prevent current reaching the pipe, in negative areas, where a pipe crosses or comes near to a trolley line or other underground metallic structures to which it is highly negative.

The costs of installing insulating coverings of the character referred to will vary over fairly wide limits, depending upon the size of the pipe, the length to be covered, the character of the soil, and the depth of the pipe, etc. In 1915 the cost of boxing and covering 500 feet or more of 8-inch line laid at a depth of about 30 inches in ordinary soil averaged about one dollar per foot. In 1919 this figure had increased to about three dollars per foot.

2. Insulating Joints.

(a) *New Work.* The value of insulating joints in pipes as a means of preventing or reducing electrolysis has long been recognized, but the manner of employing them has not always been such as to accomplish the desired end. Their effectiveness will depend very largely upon the frequency with which they are installed in any pipe line and somewhat upon other factors, such as the resistivity of the soil, the magnitude of the potential gradient in the earth and the degree of isolation maintained with respect to other underground structures.

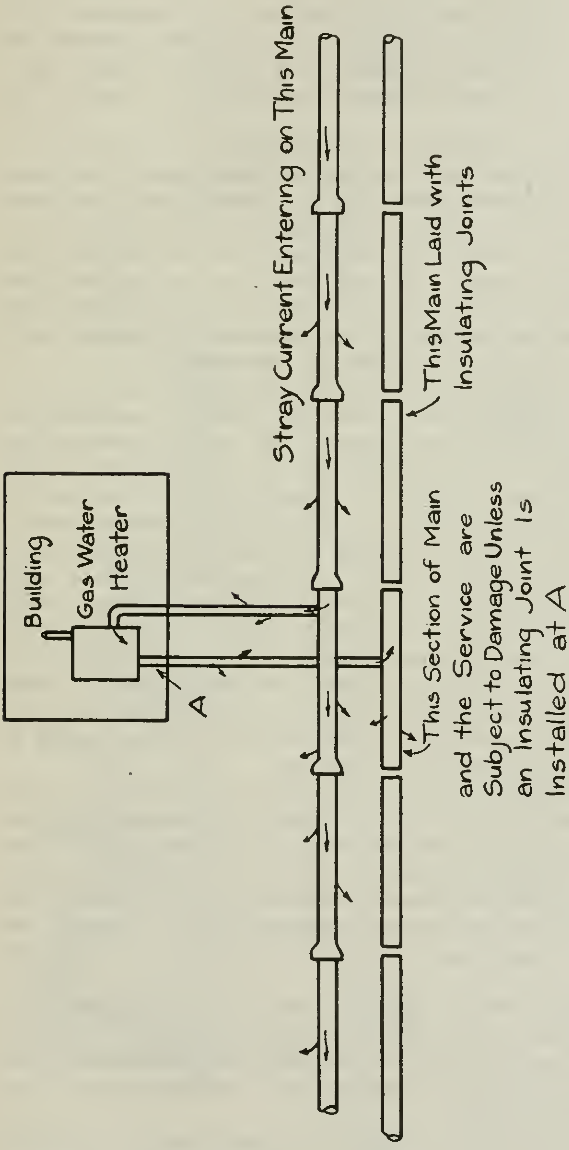
Current flow on metallic pipe lines can be practically prevented by using a sufficient number of insulating joints. A pipe line laid with every joint an insulating joint has a comparatively high resistance, and no substantial current can flow on such a line.

It is sometimes possible to break up the electrical continuity of the line and substantially protect it from electrolysis by the use of a comparatively few insulating joints, but in these cases tests should be made to see that the longitudinal flow of current along the pipe has been practically eliminated.

The services can be prevented from making electrical contact with other systems by the use of insulating joints within the premises served, as shown in Fig. 18. Without the insulating joint in the service pipe, stray current could enter from the other piping system and injure both the service and the section of main to which it connects.

Some gas companies, principally natural gas companies, have established the practice in all new work of insulating services at the meter connections within the premises, thus preventing the flow of current between gas and water services. If this is generally applied on new mains of considerable length, it is also advisable to install insulating joints at selected locations on the main.

(b) *Cement Joints.* Cement joints have long been used on gas mains and have been found to preserve a high resistance over a long period of time, and if used in sufficient numbers they are effective in preventing the flow of stray current on pipe lines. The standard cast iron bell has been used successfully with cement joints on small mains but some gas companies have had difficulty in using cement on mains 12 inches in diameter or larger. Cast iron pipe is now being manufactured with the bells especially designed for cement joints so that they



Showing Necessity of Installing Insulating Joints in Services Connected to Mains Laid with Insulating Joints

Fig. 18.

can be used on large size mains. This joint, illustrated in Fig. 19, is known as the type B joint, as covered by the specifications of the Committee on Cast Iron Pipe Joints of the American Gas Association. The calking recess is unusually long and has a slight taper whereby the joints are tightened when the pipe line contracts. When properly made, these joints have a mechanical strength considerably in excess of the pipe itself.

(c) *Leadite and Metallium.* Other substitutes for lead, such as "Leadite" and "Metallium," are being used on water mains. Some years ago the Bureau of Standards made tests on "Leadite" joints and found this material when new to have a very high electrical resistance, comparable with that of cement, but after several years in service to decrease in resistance to only a very small fraction of the original value. The change was attributed to the slow oxidation of the sulphur contained in the compound, resulting in the production of sulphuric acid. No corresponding data are yet available on "Metallium."

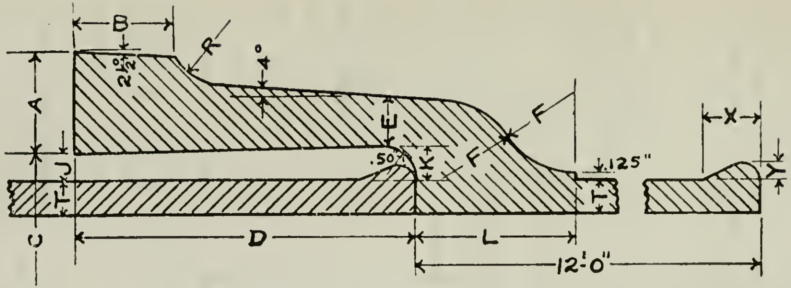
(d) *Dresser Couplings* of the ordinary type which have been extensively used on wrought iron and steel gas mains are uncertain and variable in their resistance, depending upon the manner in which they are installed. However, if used throughout any pipe line their average resistance is so high as to practically eliminate the flow of stray current.

(e) *Special Insulating Joints.* A special high resistance joint is made, known as the "Dresser Insulating Coupling," and is used to prevent the flow of stray current on pipes. Insulating joints, such as wood stave joints, and flange joints with insulated bolts and gaskets of insulating material are sometimes used on large mains at river crossings or at points of intersection with street railways and at other special locations. The effective length of such joints can be increased by thoroughly insulating the pipe with wrappings or covering for some distance on either side of the joint. This treatment is often applied to important oil and high pressure gas pipe lines.

(f) *Insulating Joints Applied to Existing Pipe Lines.* Pipe lines acting as ties between two extensive systems or networks sometimes carry considerable current from one system to the other and this can be reduced or practically eliminated by the use of comparatively few insulating joints installed in the main connecting the two systems. To distribute the stray current around insulating joints so installed, the joint can either be made long or the pipe insulated for some distance on either side.

A large industrial plant or a small community may be supplied with gas or water through a single pipe over which stray current may flow and cause damage at some point which would otherwise not be in danger. The use of one or more insulating joints will often correct such a condition at little expense.

A pipe line crossing under an electric railway track or through a river or wet ground can be prevented from discharging or collecting current at such points by the use of insulating joints on both sides of the exposure.



$X = \begin{cases} 1\ 75'' \text{ for } 4'' \text{ and } 6'' \\ 1.00'' \text{ for } 8'' \text{ to } 48'' \end{cases}$

$Y = \begin{cases} 19'' \text{ for } 4'' \text{ and } 6'' \\ .25'' \text{ for } 8'' \text{ to } 48'' \end{cases}$

$F = E + K$

Nom. Diam. Inches	Actual Outside Diam. Inches	T	Actual Inside Diam. Inches	DIMENSIONS IN INCHES										Approximate Weight in Pounds			Ultimate Tensile Strength of Pipe M lbs.	Ultimate Strength all Cement Joint M lbs.
				A	B	C	D	E	F	J	K	L	R	Bell	Per Foot	12'-0" length		
4	4 80	40	4 00	1 30	1 50	5 80	4 00	59	1 22	50	63	1 90	75	25	19 3	232	66 4	135 8
6	6 90	43	6 04	1 40	1 50	7 90	4 00	62	1 25	50	63	2 00	80	35 5	30 3	363	104 8	195 2
8	9 05	45	8 15	1 50	1 50	10 05	4 50	69	1 32	50	63	2 10	80	51 5	42 3	508	146 0	298 6
10	11 10	49	10 12	1 50	1 50	12 10	5 00	69	1 32	50	63	2 10	90	64 7	56 5	678	196 5	418 8
12	13 20	54	12 12	1 60	1 50	14 20	5 00	75	1 38	50	63	2 20	1 00	84 2	74 3	891	257 3	498
16	17 40	62	16 16	1 80	1 75	18 40	6 00	90	1 53	50	63	2 50	1 10	146 8	115 3	1373	393 7	820 0
20	21 60	68	20 24	2 00	1 75	22 85	6 00	97	1 72	63	75	2 80	1 15	198 3	156 3	1875	533	1018
24	25 80	76	24 28	2 10	2 00	27 05	6 00	1 05	1 80	63	75	2 80	1 25	259 5	208.4	2501	721	1216
30	31 74	85	30 04	2 30	2 00	32 99	6 50	1 15	1 90	63	75	3 00	1 30	363 7	286 3	3456	995	1646
36	37 96	95	36 06	2 50	2 00	39 21	6 50	1 25	2 00	63	75	3 20	1 40	472 7	384 4	4613	1338	1968
42	44 20	1 07	42 06	2 80	2 00	45 45	6 75	1 40	2 15	63	75	3 40	1 45	631 8	505 5	6066	1716	2397
48	50 50	1 26	47 98	3 00	2 00	51 75	7 00	1 50	2 25	63	75	3 60	1 60	788 3	674 6	8093	235	2857

FIG. 19.

Service pipes which are subject to corrosion at points where they cross under railway tracks are often insulated from the mains by the use of insulating joints at times of replacements, thus preventing the further passage of current from the main to the service.

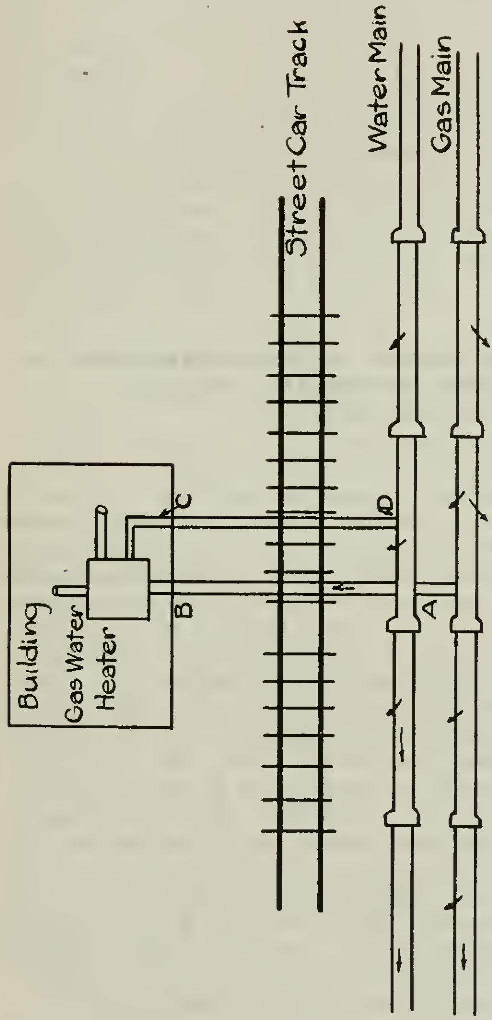
Insulating joints are also frequently used to prevent the interchange of current between two piping systems, as shown in Fig. 18, or between a piping system and a cable system or other underground structures. In order to protect gas services or water services where they cross under tracks, it is often necessary to install insulating joints both at the main and within the premises to prevent the flow of current from services of another system to which they may connect. This condition exists where gas water heaters are in use, as these appliances usually make a firm metallic contact between the gas and water services. In Fig. 20, if the gas and water mains are both positive to the track, accelerated corrosion will take place on the services where they cross under the track. To protect one service without regard to the other, it is obviously necessary to install insulating joints at A and B, or C and D.

Insulating joints have been installed at selected locations by some gas and water companies as an auxiliary to a negative feeder system. For example, in Providence, Rhode Island, after an insulated negative feeder system was put in operation insulating joints were installed on gas and water mains to still further reduce the stray current on the pipes.

The cost of installing insulating joints when pipes are uncovered for repair or replacement is comparatively a small item, and often affords a satisfactory means of preventing further damage to them.

3. Shielding.

In special cases underground structures have been protected from electrolysis by connecting to the structure an auxiliary, metallic conductor located so as to cause the current to flow to earth from the auxiliary conductor. This mode of protection is known as shielding. The method has in some cases been applied to the dead end of an underground metallic structure which is highly positive to earth. In such cases an auxiliary shielding plate or pipe of adequate ground contact surface extending beyond the dead end and electrically connected to the structure to be protected has been installed in such a manner that the bulk of the current was caused to leave the auxiliary shielding conductor, thus affording a certain degree of protection to the dead end of the structure. One application of this method which is in use is that of a service pipe crossing under tracks or crossing other structures to which it is positive and where the pipe comes relatively close to the rails or other structures at the point of crossing. In these cases a larger shielding pipe, usually of heavy cast iron, has been placed around the service pipe and electrically connected to the service pipe and extended sufficiently on each side of the crossing so that the major part of the current was caused to leave the shielding pipe, thereby corroding the latter while protecting the service pipe.



Service Pipes Being Damaged Under Car Tracks By Electrolysis To Protect Either Service Pipe It Is Necessary to Install Two Insulating Joints in the Service, One at the Main and One in the Building.

Fig. 20.

It is very important that a thorough metallic connection be made between the pipe to be protected and the shielding pipe. Otherwise, the service pipe is likely to corrode where current leaves it to flow through earth to the shielding pipe. Unless the shield is in the form of a pipe completely surrounding the structure to be protected, this method of protection is uncertain and should be used only in very special cases. When applying this method it has been found necessary to take care that the auxiliary shielding conductor does not merely increase the electrode area from which the current leaves, because in this case the current will continue to leave from the structure which is to be protected unless an insulating covering is applied to the pipe beyond the protecting shield. This has been found to be the practical result where a shielding conductor of the same or less contact area was placed in the earth near the structure to be protected and where the stray current has left both structures.

III. MEASURES INVOLVING INTER-CONNECTION OF AFFECTED STRUCTURES AND RAILWAY RETURN CIRCUIT

A. ELECTRICAL DRAINAGE OF CABLE AND PIPE SYSTEMS

Electrical drainage consists in connecting the affected structure to the railway return circuit by insulated conductors in such a manner that the current leaves the structure through these connections instead of flowing to earth. This prevents corrosion in the neighborhood of the drainage connections, but increases the current flowing on the structure and the voltage drop along it, which latter results are generally undesirable for reasons discussed in detail in subsequent paragraphs.

Drainage connections are usually made by running copper cables either to the busbar of the railway supply station or to negative return feeders. Connections to tracks should be avoided because the failure of rail bonds might cause dangerous currents to flow over the drainage connection and also because of the possibility of getting a current reversal, particularly when the adjacent substation shuts down during the light load period. However, when insulated negative feeders are used, the drainage connections may be made to the rail terminals of the feeders. Connections to rails are sometimes installed where a conduit line or a pipe crosses a railway track at a considerable distance from the power supply station and other means of draining would be awkward and expensive, but they should be made with considerable discretion and should be carefully recorded and regularly inspected.

Where used, drainage should be reduced to a minimum consistent with the protection of the drained structure in order to reduce the hazard to other adjacent underground systems.

The drainage of one system tends to establish differences of potential between the various underground systems, resulting in interchange of current with consequent injury to the system at the higher potential. In order to avoid this condition, it is desirable to interconnect the various systems and drain them over common conductors. As structures owned by different interests cannot be bonded together except by an agreement between the owners this has frequently of itself made it impossible to apply a comprehensive drainage system to all structures because of the impossibility of obtaining an agreement of all owners to allow connections to their structures, except on condition that other interests assume liability for any injury which may result from such interconnections.

If, however, the foregoing method of unified drainage is carried out so that the drained structures are at all times negative to earth, no electrolytic corrosion of such structures will result. Just how difficult it may be to maintain pipes negative to earth at all points and at all times by means of drainage is a question which cannot be answered until investigations have been carried further.

The objections to electrical drainage apply most forcibly to pipe networks, particularly to gas and oil pipes on account of the inflammable substances carried. Drainage should be considered only as a supplementary measure to the improvement of the railway return circuit or as a temporary measure in cases where acute electrolytic corrosion has resulted. It can never take the place of an adequate railway return circuit.

Notwithstanding its numerous disadvantages and limitations, there are engineers who believe that pipe drainage has a definite field of usefulness. The Committee, through its Research Sub-Committee, is still actively engaged in investigating the magnitude and importance of the technical factors involved and until further information shall have been acquired, the Committee will not be in a position to reach a conclusion on this subject.

1. Drainage of Cable Sheaths.

(a) *Method of Draining Cable Sheaths.* In order to afford complete protection to cable systems, it has been found that they should be interconnected and have drainage conductors of sufficient conductivity located so that the lead sheath of the cable network is everywhere lower in potential than the adjacent earth. Cable systems are usually installed in vitrified clay, creosoted wood, or fibre ducts, and if kept free from water, the tendency to collect current is much less than if they were in direct contact with the earth. Owing to the higher resistance thus introduced between cables and earth and the continuous character of the cable sheaths, it is usually possible to lower the potential of the system below that of the adjacent earth in all localities by draining relatively small currents at one or more points.

In order to prevent the interchange of current through earth between the several cable sheaths in any conduit system, it is necessary to bond the sheaths together at frequent intervals. Some companies make a practice of bonding at every manhole and good practice requires such bonding at intervals not to exceed five hundred feet. Bonding is usually accomplished by sweating a flat copper strip or a copper cable to all cables within any system which may properly be bonded together. Foreign cables which enter any duct system are also bonded to the system they parallel. It is often necessary to interconnect signal cables with lighting and power cables so as to avoid differences of potential which might otherwise occur, but where this is done, a fuse should be installed in the bond connection to the signal cable so as to eliminate the possibility of high voltage current getting on the signal cable sheaths.

It is desirable to provide means for measuring all drainage currents and where the drainage feeder is extended to the supply station, an ammeter or shunt is usually installed for that purpose within the station. Where the drainage cable does not enter the supply station, measurement can be made within a manhole or on a pole, or wherever the drainage cable is accessible.

Where a cable system tends to become positive in regions remote from the railway supply station, it is necessary either to use a long copper cable for drainage at a considerable expense or to resort to some other method of protection. Aerial telephone cables are sometimes used for this purpose, but are not employed except where other conductors are not available or would be unduly expensive.

Cables are sometimes found to be positive only during certain periods of the day or their potential may reverse from time to time due to fluctuations in the railway load. Where this condition is considered dangerous from the electrolysis standpoint an automatic switch is sometimes installed which is closed during the period the cable is positive and automatically opens when the cable becomes negative, the object being to prevent the cable from taking on current while in a negative condition. The cost of automatic switches and the fact that they add an objectionable complication to the plant are reasons why their use should be restricted as much as possible.

Automatic or manually operated switches should be provided in all drainage cables terminating in railway supply stations in order that they may be opened during the period when the station is not in operation. Automatic substations which start and stop without attendants should be provided with facilities for accomplishing this result.

(b) *Heating Effect of Stray Current on Cable Sheaths.* Stray current on the sheaths of lead covered cables causes a heating effect which impairs the carrying capacity of power cables. In some cases this effect may be objectionable.

The following formulae have been developed for single conductor and three conductor cables to give their current carrying capacity when sheath currents flow. The values obtained give the conductor the same temperature rise above surrounding structures as produced by their normal current when no sheath currents are present.

The formulae have been developed on the following basis:

1. That the watts dissipated in the sheath are effective in raising the sheath temperature but that they do not affect the rise of the conductor over the sheath.

2. Resistivity of lead 12 times that of copper. This assumption, while not strictly correct, will give results within an accuracy obtained by considering other factors as constants, such as the radiation constants of the lead sheath.

Definitions

A = temperature rise of conductor over sheath for a given conductor current.

B = temperature rise of sheath over cable surroundings for the same conductor current as for A.

C = temperature rise of conductor over cable surroundings for the same conductor current as for A and B.

D = outer diameter of lead sheath in inches.

d = inner diameter of lead sheath in inches.

a = area of conductor in circular inches $= \dfrac{\text{area in circular mils}}{1{,}000{,}000}$.

I_s = amperes flowing in sheath.

I_o = normal current rating of cable.

X = defined as $\dfrac{I_s}{I_o}$.

I = conductor current with (XI_o) sheath currents.

For Single Conductor Cable

$$I = I_o\sqrt{1-\frac{12a\,X^2\,(C-A)}{(D^2-d^2)\,C}}.$$

For Three Conductor Cables

$$I = I_o\sqrt{1-\frac{4a\,X^2\,B}{(D^2-d^2)\,(A+B)}}.$$

The values of A, B, and C can be found for single and three conductor cables by referring to Atkinson's article on "Carrying Capacity of Cables" in the September, 1920, issue of the Journal of the A. I. E. E.

Examples

1. Single conductor cable, 250,000 C. M., 1/8 inch lead sheath, 4/32 inch paper insulation. Normal current 510 amperes. What is resultant carrying capacity with 100 amperes sheath current?

$$X = \frac{100}{510} = .196,\ X^2 = .0384.\quad a = .250,\ \frac{C-A}{C} = \frac{18.4}{25.0} = .735.$$

$$D = 1.09,\ d = .84,\ D^2 - d^2 = .484.$$

Resultant carrying capacity $= 510\sqrt{1-\dfrac{12\,(.250)\,(.0384)\,(.73)}{.484}} =$ 510 (.91) = 463 amperes.

2. Round Three Conductor No. 4/0, $\dfrac{6\times 6}{32}$ paper insulation,

1/8 inch lead sheath. Normal current 242 amperes. What is resultant carrying capacity with 200 amperes sheath current?

$$X = \frac{200}{242} = .827,\ X^2 = .684,\ a = .2116,\ \frac{B}{A+B} = \frac{11.3}{15.0+11.3} = .43.$$

$$D = 2.61,\ d = 2.36,\ D^2 - d^2 = 1.25.$$

Resultant carrying capacity $= 242\sqrt{1 - \frac{4\,(.2116)\,(.684)\,(.43)}{1.25}} =$ .893 (242) = 216 amperes.

In a similar way the reduction of current carrying capacity for certain cables has been calculated in Tables 1 to 4. Tables 1, 2, and 3 are for single conductor cables for 250 volt, 2,300 volt, and 600 volt service, respectively. Table 4 is for 13,200 volt, 3 conductor cables.

The normal ampere rating in the second column of Tables 1 and 2 for rubber insulation is based on the following formula.

$$I = \sqrt{\frac{T_1 - T_2}{r\left(\frac{K}{2\pi}\log_e \frac{d_2}{d_1} + \frac{J}{\pi d_2}\right)}}$$

Wherein the following terms are used:

d_1 = diameter of copper in inches.
d_2 = diameter over insulation in inches.
d_3 = diameter over sheath in inches.
K = resistivity of insulation in degrees C. rise per watt per inch cube.
J = radiation resistivity of lead sheath to ambient surroundings in degrees C. rise per watt per inch square.
r = resistance of conductor at T_1, per inch length.
I = current carrying capacity of cable.
T_1 = permissible copper temperature, in degrees C.
T_2 = temperature of ambient surroundings in degrees C.

In solving the formula, the following values of the several constants were taken:

K = 300°C. rise per watt per inch cube.
J = 200°C. rise per watt per inch square.
T_2 = 40°C.

The normal ampere rating in tables 3 and 4 for paper insulation is based on the data in the paper entitled "High-Tension, Single-Conductor Cable for Polyphase Systems," by W. S. Clark and G. B. Shanklin, Transactions of the A. I. E. E., 1919, Vol. XXXVIII, page 917.

The conductor temperatures used are in practical agreement with Rule 9100, page 95, Revision of 1921 of the Standards of the American Institute of Electrical Engineers.

Where different normal ampere ratings or temperatures are used, the percentages of normal current that can be carried with various sheath currents will differ from those given in these tables.

Naturally, the effect of sheath currents is greater for small and medium sized cables, and it may be noted that cables of these sizes and types are most commonly met in complicated distribution networks.

Also, for the same size conductor, a given sheath current will reduce the current carrying capacity of the cable to a lesser extent as the insulation thickness is increased.

In cases where drainage must be employed and where heating is a factor, the sheath currents can be reduced to a mimimum by limiting the drainage to the smallest values which will protect the system.

TABLE 1.

EFFECT OF SHEATH CURRENTS ON ALLOWABLE CONDUCTOR CURRENT OF SINGLE CONDUCTOR 250-VOLT 2/32" RUBBER INSULATION. SHEATH ASSUMED 1/16" THICK.

Conductor size	Normal ampere rating at 60° C. Conductor temp. 40° ambient	Per cent of normal rating which can be carried with sheath currents as indicated				
		10 amp.	20 amp.	30 amp.	40 amp.	50 amp.
No. 6....	56	96.0	83.0	54.3	....	....
4....	75	96.8	86.6	66.0	....	....
2....	101	97.7	90.2	76.0	49.5	....
1/0*..	137	98.3	93.0	83.0	66.8	37.2

* Thickness insulation = 5/64"

TABLE 2.

EFFECT OF SHEATH CURRENTS ON ALLOWABLE CONDUCTOR CURRENT OF SINGLE CONDUCTOR 2,300-VOLT 6/32" RUBBER INSULATION. SHEATH ASSUMED 3/32" THICK.

Conductor size	Normal ampere rating at 60°C-.25E Conductor temp. 40° ambient.	Per cent of normal rating which can be carried with sheath currents as indicated.						
		10 amp.	20 amp.	30 amp.	40 amp.	50 amp.	60 amp.	70 amp.
No. 6......	60	99.2	96.2	90.9	82.7	71.9	55.5	23.5
4......	79	99.2	96.5	92.0	85.3	75.8	62.2	34.6
2......	106	99.3	97.3	93.7	88.5	81.0	71.0	57.1
1/0.....	139	99.4	97.6	94.4	89.5	83.0	74.3	62.6

TABLE 3.

EFFECT OF SHEATH CURRENTS ON ALLOWABLE CONDUCTOR CURRENT OF SINGLE CONDUCTOR 600-VOLT 4/32" PAPER INSULATED CABLES. SHEATH ASSUMED 1/8" THICK.

Conductor size	Normal ampere rating at 85°C Conductor temp.	Per cent of normal rating which can be carried with sheath currents as indicated.						
		50 amp.	75 amp.	100 amp.	125 amp.	150 amp.	175 amp.	200 amp.
250,000 c.m.	510	97.8	96.4	91.0	85.5	78.3	68.7	55.7
500,000 c.m.	720	98.0	95.7	92.2	87.5	81.5	73.6	63.3
750,000 c.m.	880	98.3	96.3	93.3	89.4	84.3	77.8	69.7
1,000,000 c.m.	1,010	98.5	96.7	94.0	90.3	85.7	80.0	72.7
1,500,000 c.m.	1,250	98.8	97.2	94.5	91.8	88.0	83.3	77.5
2,000,000 c.m.	1,440	98.8	97.3	95.4	92.7	89.3	85.0	80.0

TABLE 4.

EFFECT OF SHEATH CURRENTS ON ALLOWABLE CONDUCTOR CURRENT OF ROUND THREE CONDUCTOR 13,200-VOLT 6/32 BY 6/32 PAPER INSULATED CABLES DUE TO STRAY CURRENTS FLOWING ON SHEATH. SHEATH ASSUMED 1/8" THICK.

Conductor size	Normal ampere rating at 75° C. Conductor temp.	Per cent of normal rating which can be carried with sheath currents as indicated						
		50 amp.	75 amp.	100 amp.	125 amp.	150 amp.	175 amp.	200 amp.
1/0.........	173	99.3	98.4	97.3	95.6	93.5	91.2	88.3
2/0.........	193	99.3	98.4	97.2	95.6	93.5	91.3	88.4
3/0.........	218	99.4	98.5	97.3	95.5	94.0	91.8	89.1
4/0.........	242	99.4	98.5	97.5	95.5	94.0	91.3	89.3
250,000 c.m..	263	99.4	98.6	97.6	96.2	94.4	92.3	89.8
300,000 c.m..	290	99.4	98.6	97.8	96.5	95.0	93.0	90.7
350,000 c.m..	312	99.4	98.7	97.7	96.4	94.8	93.0	90.6

Good duct construction with vitrified clay or fibre conduit for laterals and main conduits, and the draining of manholes to sewers or by sumps will tend to increase the resistance of the cables to earth, and thereby reduce the tendency to collect stray currents. On the other hand, thorough grounding of sheaths is in many cases resorted to as a protective measure for isolated sections.

Where it is impossible to protect cable systems by natural drainage, boosters have occasionally been used to artificially lower the potential of the cable system. This practice, as well as the over drainage of cable systems, is objectionable where other underground structures are involved, as it may result in unusually high potential differences between the piping and cable systems with resulting damage to the pipes.

2. Difference Between Cable Drainage and Pipe Drainage.

The early use of drainage as a method of affording protection against electrolysis of lead covered cables led to the proposal to apply the same method of protection to underground piping systems. The result is that more or less pipe drainage has been used, particularly on water systems and to a limited extent on gas systems. While the success of protecting cable systems by drainage is generally recognized, there are important differences in the application of drainage to cables and to piping systems which make the application of drainage to the latter difficult and uncertain. Among the important differences between the drainage of cable and piping systems are:

1. Cables are electrically continuous and uniform conductors, while pipes are not uniform conductors and are sometimes discontinuous conductors due to the joints in them. Experience indicates that in mains having cement joints a large percentage of these joints are of high resistance, and in mains having lead joints, occasional joints of very high resistance are found and many of the joints have resistances higher than several lengths of pipe. Therefore, drainage will lower the potential of the pipe for relatively short distances from the drainage taps, so that to be effective a greater number of drainage taps must be installed than for a cable system of the same extent. The number and location of taps will depend upon the extent and physical layout of the pipe network, and the expense involved will depend upon the number and locations of the taps required.

2. Under certain conditions there is a tendency for current flowing on a pipe to leave it on the positive side of a high resistance joint, returning to the joint on the negative side, or else to flow to another structure. As a result of this, joint corrosion may occur at high resistance joints unless both sides of the joint are maintained negative or neutral to the adjacent earth at all points and under all conditions; and conversely, no electrolytic corrosion will occur on either side of a high resistance joint if the entire surface of both the adjacent pipe lengths is permanently negative to the surrounding earth. The difficulty of keeping a complicated network of pipe negative to the adjacent earth by means of drainage is much greater than in the case of cable systems.

3. Cable systems are placed in ducts with manholes conveniently spaced so that the effect of the application of drainage to a cable system may be adjusted so as to produce the results desired, whereas with pipes buried in the ground, and in large cities beneath improved pavements, it is more difficult to make the necessary measurements to ascertain the effects of drainage.

4. Cables are relatively small and contained in ducts so that unless they are in wet or marshy ground, they are but partially in contact with the earth, whereas, gas or water pipes are buried directly in the earth. Because of this condition, the drainage of an underground piping system with but few high resistance joints results in the flow of larger amounts of current than does the drainage of a cable system.

5. Currents flowing in piping systems conveying inflammable substances, such as gas or oil, constitute a fire and explosion hazard and many cases have been reported where stray currents have caused arcs which have ignited the gas or oil when the continuity of the pipe was broken. One of the objections to the presence of excessive currents

on gas or oil pipes is the necessity for bonding around a cut in the pipe whenever a pipe is opened for repairs. Under such conditions a copper wire cable is connected around the point on the pipe to be opened. Jumper cables, terminating with adjustable clamps, are used by some companies for this purpose.

Under certain conditions there is also danger of increasing potential differences between service pipes in confined air spaces which may result in causing arcs due to the intermittent contact between pipes which will puncture the gas pipes and ignite the escaping gas.

3. Application of Drainage to Pipes.

(a) *Maintaining Pipes Negative to Earth.* Investigations of the Research Sub-Committee show that when electrical drainage feeders are connected to a jointed piping system the drained pipe is maintained negative to the soil for only a few hundred feet from the point of connection. In such cases it is necessary to extend the drainage feeder along the principal pipes in the positive area, which extends theoretically about 40 per cent. of the distance from the supply station to the end of the feeding district, and connect to the pipes at frequent intervals.

(b) *Effect of Pipe Drainage on Current Interchange.* Various conditions exist in piping systems which tend to affect the interchange of current between them, and these should be fully recognized in the consideration or employment of pipe drainage.

If a single pipe system exists, as for example, a water system in a small town, the drainage of that system will not as a rule result in objectionable interchange between various parts of the network. However, there are usually several piping systems present, such as a lead calked water pipe system and a lead calked gas pipe system. If these piping systems are not interconnected at many points through appliances, or are not otherwise connected together, the drainage of one or both systems might result in serious interchange of current.

The application of drainage to one piping system in a territory where another piping system exists may result in an interchange of current between the drained and undrained systems, so it is necessary to resort to the common drainage of all of the piping systems to be protected, as the potential inequalities created by separate drainage cause electrolysis at points where the current leaves the undrained system to find its path to the drained system. Even with the most carefully installed and maintained unified system of drainage, it cannot be expected that all danger from current interchange will be eliminated.

Pipe systems laid with cement joints, Dresser Joints, or other high resistance joints and not interconnected with other systems, will usually need no other form of protection against electrolysis. If, however, such a system exists in a territory also occupied by a piping system with lead calked joints and connected to it at many points through appliances or otherwise, the service pipes of the system with the high resistance joints and the sections of the mains to which they are connected, will be electrically connected to the more continuous system and so far as electrolysis is concerned should be considered as a part of that system. Any electrolysis condition existing on the continuous system will therefore be experienced by such service pipes and the sections of the mains of the discontinuous system as connect directly with it and any measure which tends to protect the continuous piping system will also affect the services of the discontinuous system. This condition is illustrated in Fig. 18, where a continuous water piping system is connected through appliances to gas services. Although the gas mains are laid with cement joints, they are being damaged by current brought to them over the water mains.

The application of pipe drainage under conditions here described may afford protection to some portions of the piping system and increase the damage to others. In some areas gas services and water services are connected with each other through appliances so that at these locations the two piping systems are maintained at practically the same potential. In most piping networks, however, there will be extensive areas where the gas and water systems are not interconnected by such appliances and even where they do exist they cannot always be relied upon to maintain the two systems at practically the same potential.

(c) *Effects of Different Kinds of Pipe and Joints.* A fundamental difficulty in applying electrical drainage to piping systems is usually present and this is the great variation of conductivity of different kinds of pipes and of different joints. In any cast iron piping system the resistance of the joints varies through wide limits. In many cities there are a number of different kinds of pipes in use: steel mains with welded or screw joints have a low resistance; steel mains with gaskets made of rubber are high in resistance, while cast iron mains with cement joints are unusually high in resistance. With electrical drainage the current on the pipes is increased and the potential drop along these pipes and over the joints is increased in like proportions.

Because of these conditions it is difficult to apply drainage without increasing the potential differences between the different piping systems at some points.

SUMMARY OF GOOD PRACTICE

This summary is intended only as an annotated index or guide to the contents of Chapter 2 of this report, not as a substitute. Before forming an opinion or taking even preliminary action on any subject treated in the report the full text should be studied.

A. RAILWAYS

1. Track Construction and Bonding.

(a) The use of heavy rails with joints properly bonded and well maintained is the first requirement for good track conductivity and the minimizing of stray currents.

(b) In paved streets welded rail joints are regarded as the best and most permanent form of bonding.

(c) Rail joints including 3 feet of rail which have a resistance in excess of 10 feet of adjacent rail should be rebonded, except joints bonded with long bonds, which should be renewed when the resistance exceeds that of 15 feet of adjacent rail.

(d) Bonded joints should be tested at least once each year and such tracks as show bond failures in excess of 5 per cent. annually should be tested every six months. A failure is here defined as exceeding the resistance specified in paragraph (c).

(e) Cross bonds, connecting the two rails on single track, and the four rails on double track should be installed at intervals not to exceed 500 feet in city systems and from 1,000 to 2,000 feet on interurban lines.

(f) Jumpers of one or more conductors should be used around all special work, and should connect to all rails on both sides of the special work. The size of such jumpers should be proportioned to the current on the rails, but in no case should they be smaller than No. 0000 for one track. In addition, where practicable, all special work should be bonded and maintained as other track rails.

2. Track Insulation.

(a) In the construction of electric railway tracks and roadbeds the electrolysis problem should be given consideration with economy of construction, maintenance, and operation.

(b) Roadbeds should be constructed with as high electrical resistance to earth as consistent with other considerations, special attention being given to keeping them dry by drainage. Where practicable, rails should be kept out of contact with the earth.

(c) Clean crushed stone ballast offers a much greater electrical resistance to stray current than does solid concrete as a foundation under ties.

(d) Where crushed stone or gravel ballast is used it should be kept clean. If earth, sand, or street dirt is permitted to filter into ballast of this character its insulating property is greatly impaired. Vegetation should be kept down, as this tends to make the roadbed moist and to fill the ballast with foreign material.

(e) Salts, which are often used to prevent freezing at switches and frogs, greatly reduce the resistance of roadbeds and should be avoided as much as possible.

(f) Zinc chloride and similar chemical tie preservatives reduce, while creosote and gas oil increase the electrical resistance of ties.

3. Reinforcement of Rail Conductivity.

Copper is not economically employed when connected in parallel with tracks, and therefore subjected to the same voltage drop as exists on the tracks, as it cannot be loaded to capacity with track voltage drops ordinarily permissible.

Buried copper conductors or old rails used to supplement the track return also increase the contact area between the return circuit and the earth and thereby tend to augment stray currents. For these reasons the use of such supplementary conductors should be avoided.

4. Power Supply.

(a) Power supply stations for electric railways should be located with consideration to their effect on overall potentials and potential gradients in the tracks.

(b) In selecting locations for substations, particularly for interurban lines, consideration should be given to the extent and character of the underground metallic structures in their immediate vicinities.

(c) Connections to tracks in wet locations or the installation of bare track feeders in earth or in water courses should be avoided.

(d) Numerous independent connections to the track for the return of current afford the most effective means of reducing high potential gradients and overall voltages and thereby limiting stray currents, and as many should be provided as consistent with good engineering and economic considerations.

This can be accomplished by the use of additional power supply stations, by the installation of insulated negative return feeders, or by the three-wire system wherein each car on the negative trolley becomes a point of return. Combinations of these may also be employed.

(e) The most generally satisfactory method of increasing the number of independent return points on a track system is by the use of additional substations and the tendency of railway practice is now in this direction.

(f) Considerable progress has been made in recent years in the development of automatic, semi-automatic, and remote control substations and these are now being used both on interurban lines and for city service. The economies attending such substations make possible a greater number of feeding points than can economically be supplied through manually operated stations.

(g) By employing the maximum number of substations consistent with economy, rather than the minimum number, stray currents will be greatly reduced.

5. Interconnection of Tracks.

As a rule, interconnection of tracks will improve general electrolysis conditions, but may be detrimental in one locality while improving conditions in another.

6. Insulated Negative Feeder System.

(a) Track gradients and overall potentials can be limited to any desired extent by the use of insulated negative feeders but the cost of such installations, the additional power loss accompanying their use and the reduction in operating voltage at the cars may make their use uneconomical except in connection with frequent power supply stations.

(b) In general in the application of insulated negative feeders, the negative bus should be connected to the track at more than one point, that is, negative feeders should be extended along the track to nearby intersections. Small stations of 300 to 500 k.w. capacity in city networks may usually be connected directly to the track at one point only and preferably to the nearest track intersection.

(c) Insulated negative feeders should be run from the negative bus to the rails in such a manner as to insulate them thoroughly from the earth and from each other. The tying together of any of these feeders should be avoided. In some cases, however, it may be allowable to tie a single feeder to the rail at two or more points through resistances to adjust the currents drawn from the tracks at the various points of connection.

(d) Connections to tracks should preferably be made in dry rather than in wet locations.

(e) Means should be provided on all negative feeders and feeder taps for conveniently measuring the current flow thereon and where practicable these means should be installed within the power supply station.

(f) Insulated negative feeders are not as well adapted to reducing stray currents from interurban lines as from city networks.

7. Three-Wire System.

(a) The three-wire method of railway power supply will greatly reduce stray currents when properly applied and also give better operating voltage at the cars.

(b) Where a few large supply stations are used the first cost of converting an existing railway system for three-wire operation is usually smaller than the first cost of any other measure which will give the same degree of protection from electrolysis.

(c) There are difficulties to be encountered in connection with three-wire operation which should be carefully considered before adopting that system.

8. Reversed Polarity Trolley System.

(a) With reversed polarity the amount of stray current is not reduced but the electrolytic corrosion will be scattered over the outlying districts instead of being confined to the vicinity of the power supply station. With reversed polarity the drainage of cable sheaths is rendered impracticable.

(b) This measure should not be considered except as a temporary means of relieving dangerous conditions in the vicinity of the power supply station at the expense of the cables and piping systems at a distance from the station, pending the installation of an effective method of electrolysis mitigation.

9. Periodic Reversal of Trolley Polarity.

(a) If the polarity of the trolley system is reversed daily, electrolytic corrosion will be materially reduced although the drainage of cable sheaths will be rendered complicated or impracticable.

(b) Some of the difficulties attending three-wire operation will also be encountered with the periodic reversal of the trolley.

10. Double Contact Conductor Systems.

(a) Practically complete immunity from electrolysis can be had by the use of a properly maintained double contact conductor system either underground or overhead, but the expense and difficulties involved in such installation are not justified merely as a means of electrolysis protection.

11. Alternating Current Systems.

(a) Electrolysis resulting from the use of alternating current by street railways is negligible.

B. AFFECTED STRUCTURES

1. Location with Respect to Tracks.

(a) The close approach of piping systems to railway tracks and the laying of shallow service pipes under tracks should be avoided as far as practicable.

(b) On streets in positive areas where car tracks exist gas and water mains are sometimes installed on both sides of the streets. Such construction permits the use of shorter services and obviates the necessity for placing service pipes under tracks.

2. Avoidance of Contact of Cables with Pipes and Other Structures.

(a) In the installation and maintenance of cable systems precautions should be taken to avoid contact between lead sheaths and other underground structures, such as foreign cables, rails, steel bridges, gas or water pipes and the steel frames of buildings, except as such contacts may be required for specific reasons.

3. Conduit Construction.

(a) Cable sheaths should be kept out of intimate contact with the earth by the use of suitable duct materials, proper conduit construction, and adequate conduit drainage. Dips in the conduit where moisture might collect should be avoided wherever practicable.

(b) The use of iron pipe for laterals to poles and buildings should be confined to conditions where no other form of conduit is suitable or permissible.

(c) Wherever long laterals to poles are installed the horizontal portion should be of vitrified tile, fiber, stone or some similar duct material, using iron pipe only for the bend at the base of the pole and for the vertical portion up the pole.

(d) Unless necessary as a protective measure for isolated sections, cable sheaths should not be artificially grounded. Grounds in negative areas through which stray current might be picked up should be avoided whenever practicable.

4. Insulating Joints in Cable Sheaths.

(a) Insulating joints are sometimes used in cable sheaths under special conditions to prevent electrolytic injury which might result from contact with steel bridges or buildings. They are also occasionally used to prevent the flow of current on cable sheaths where drainage is undesirable or impracticable.

5. Surface Insulation of Pipes and Cables.

(a) Surface insulation in the form of dips, paints and wrappings cannot be depended upon as a permanent method of preventing electrolysis.

(b) Thick coatings in the form of pitch or parolite poured into a containing box built around the pipe are occasionally used in preventing electrolysis under special conditions where the expense is warranted.

6. Insulating Joints in Pipes.

(a) Insulating or high resistance joints, such as those of the Dresser type or cement joints, if used throughout a pipe line at frequent intervals, or at specially selected locations, may afford substantial protection against electrolysis. This practice relates particularly to gas and oil pipes.

(b) It is sometimes permissible to use a comparatively few insulating joints if care is taken to see that the flow of current on the pipe is practically eliminated.

(c) Insulating joints are often installed in service pipes for the purpose of preventing the interchange of current between pipe systems.

7. Shielding.

In special locations a pipe may be protected from electrolysis by a metal shield, wholly or partly surrounding it and electrically connected thereto.

C. INTERCONNECTION OF AFFECTED STRUCTURES AND RAILWAY RETURN CIRCUIT

1. Cable Drainage.

(a) Lead sheath cables in urban districts or where parallel with interurban railways commonly require some form of electrolysis protection and this is usually accomplished by drainage.

(b) In some cases the heating effect of stray current on the sheaths of power cables may reduce the current carrying capacity of the cable.

(c) Drainage connections should be made to the negative bus of the railway supply station or to the rail terminal of insulated negative feeders. Connections to the rails should in general be avoided.

(d) Cable sheaths when drained are made negative to the surrounding earth at practically all times. Drainage should be reduced to a minimum consistent with the protection of the cables.

(e) In general, all signal cable sheaths in any conduit system should be bonded together at every manhole. Where advisable and permissible all power cable sheaths should be similarly bonded.

(f) So far as practicable or advisable, all cable systems should be drained at the same locations or by the same drainage feeders and differences of potential between adjacent or intersecting cable systems should be eliminated by cross bonding.

(g) Fuses should be installed in all connections between signal and power cable sheaths, and should be so proportioned as to protect the sheaths from dangerous currents.

(h) Means should be provided for conveniently measuring all drainage currents and maintaining close supervision on all drainage systems, and where possible this should be accomplished by installing meters within the power supply station and making them accessible to the cable owning companies.

(i) Means and operating regulations should be provided for opening all drainage cables during periods when reverse currents would otherwise flow over them, if the magnitude and duration of such reverse currents is objectionable.

2. Pipe Drainage.

(a) There are wide differences of opinion among competent engineers who have studied pipe drainage as to its adaptability to various conditions. Numerous questions are involved in regard to which there is not sufficient information available at the present time to permit the drawing of accurate conclusions, and for this reason this subject is being investigated by the Research Sub-Committee of the American Committee on Electrolysis. There are, however, certain objections to the use of pipe drainage which are discussed in this report and which should be carefully considered before employing it.

(b) Pipe drainage is in use more or less on water systems and to a limited extent on gas systems.

(c) As a method of mitigation, drainage is not so well adapted to pipes as to cable sheaths.

(d) High resistance joints are prevalent in all jointed pipe lines and they greatly complicate the application of drainage.

(e) To lower the potential of a jointed piping system below that of the surrounding earth, it is usually necessary to extend the drainage conductors over a considerable area and connect to the pipes at numerous locations.

(f) Corrosion at high resistance joints in pipe lines carrying current may occur unless the pipe on both sides of the joint is maintained negative or neutral to the adjacent earth, in which case no corrosion will occur.

(g) Drainage generally increases the current flow on pipes and such current increases the hazard from oil and gas ignitions and explosions.

(h) In small towns on interurban railways pipe drainage is less objectionable than in urban districts where complicated pipe networks exist.

(i) Drainage of a large network of pipes should be used only as an auxiliary to a railway system, properly designed and maintained from the electrolysis standpoint. When so used it should be installed and maintained under competent supervision.

Chapter 3

ELECTROLYSIS SURVEYS

I. Introduction

A. PURPOSE AND SCOPE OF ELECTROLYSIS SURVEYS

1. Purpose of Electrolysis Survey.*

Electrolysis surveys deal with the various methods and classes of measurement employed to determine the hazard to underground metallic structures due to stray electric currents, the extent of existing damage already produced, and the mitigative measures that may best be employed for reducing the danger of future trouble. There are discussed below the methods of determining electrolysis conditions, of collecting data upon which the design of mitigating systems may be based, the types and kinds of instruments that should be used, the procedure to be followed in the working up of the data, and the interpretation of the results of the survey.

2. Difficulty of Standardizing Survey Procedure.

It should be emphasized that in general, no two electrolysis surveys will be conducted in precisely the same manner, so that specific rules of procedure cannot be laid down that will be applicable to all cases. The procedure set forth below is intended to cover the measurements that experience has shown are most frequently required, and to describe the best methods of taking such measurements. The number of readings taken and the procedure to be followed will vary so much with local conditions that reliance must be placed on the judgment of the person making the test. In fact, the proper procedure during a large part of the survey will depend in large measure on the results obtained in preliminary tests. It is important, therefore, that electrolysis investigations of any importance be made under the direction of a competent engineer very familiar with methods of procedure and the interpretation of electrolysis test data.

3. Information Obtainable by Electrolysis Surveys.

By means of proper measurements, it is possible to determine with a fair degree of definiteness, the extent and location of the areas in which pipes and other structures are endangered by stray currents and, with sufficient accuracy for most purposes, the degree of seriousness of the trouble. The cause of any damage that may be in progress at the time of the survey, whether due to stray currents or corrosion by the soil, cinders, or other natural causes, can generally be ascertained, and in the case of stray current corrosion, the source of the current can generally be determined. The various factors connected with pipe systems, such as high resistance joints, very low soil resistances, and the use of improper mitigative measures, can also be detected. Defects in the railway return system, such as poorly bonded rail joints, infrequent cross bonds, insuf-

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*For a definition of the term *electrolysis survey* and other terms used in this chapter, see Chapter 1, on *Principles and Definitions*.

ficient conductance in the negative return, improper use of such conductance, excessive feeding distances and other causes of electrolysis trouble can usually be definitely determined.

B. TYPES OF SURVEYS

In the following discussion several types of surveys must be recognized. The first is that which may be called a *complete electrolysis survey* which is made for the purpose of determining the extent and location of the danger areas, and with a view of determining the proper procedure to be followed for the mitigation of any trouble which may be found to exist.

The second type of survey, known as a *maintenance survey,* embraces such surveys as would usually be made by a pipe or cable owning company solely for the purpose of determining whether previously existing conditions have changed, and differs from the more complete survey mainly in that most of the information with respect to the railway power distribution system is not required and fewer electrical measurements are taken, the number and character of such measurements depending on the thoroughness with which the survey is to be carried out.

A third type of survey which needs little discussion, except as to methods of making tests, is one made to determine whether ordinances or regulations governing electrolysis conditions in a municipality are being complied with. Such surveys are usually made periodically, in periods varying from three months to a year. In general, only those quantities are measured which are specifically defined by the ordinances or regulations which are in effect in the locality in question.

C. GENERAL PRELIMINARY DATA

1. Data on Underground Structures.

In making electrolysis surveys, a considerable amount of preliminary data are usually desirable. It is important first to gather all evidence regarding the character, extent and location of known damage to underground structures. This evidence is usually obtained from the utility companies concerned, but even though these companies can give no direct testimony as to the injury to underground structures, this should not be taken to indicate that no damage exists. The data on the underground systems should include the relative location of the mains, the railway tracks and underground cable systems. The size and kinds of pipe and the types of pipe joints used are usually important. Numerous questions relating to the interconnection of gas, water, and cable systems are also of importance.

2. Data on Railway Systems.

As regards the data on the railway systems, the following should be determined: (1) Location and capacities of direct current railway supply stations; (2) Location of railway lines and character of service, whether city, suburban, or interurban, and the car schedules on different parts of the system. This latter will have a bearing on the length of time necessary for taking readings at various points in order to get representative results; (3) Physical data on railway tracks, such as size of rails, types of bonds and joints, and character of roadbed construction; (4) Practice of the railway company in regard to crossbonding, bond maintenance and bond testing; and (5) Miscellaneous data. In most cases it is desirable to have all-day load curves to facilitate the interpretation of data taken over short intervals at various hours of the day. Where the load varies considerably in different sections of a power house feeding area, it may be necessary to get the load curve on different feeders in some cases. Where a survey is made with the ultimate purpose of correcting electrolysis conditions by applying some method of mitigation, it will be necessary to secure complete data on the magnitude and distribution of the load, the substation and feeder systems, frequency of schedules and probable future growth of traffic.

D. COOPERATION IN MAKING SURVEYS

Special surveys for determining whether ordinances are being complied with and maintenance surveys can usually be made by any particular utility interested. Complete surveys, however, which are to be preliminary to the application of electrolysis mitigative measures should preferably be carried out on a cooperative basis by the various utilities interested, including both the railways and owners of underground utilities. It is of the utmost importance that a comprehensive plan of procedure be followed, so that all information relating to the electrolysis conditions of all of the underground structures may be available in the planning and carrying out of the test. In order to bring about such a unification of data and methods, it is necessary to have the full cooperation of all utilities whose properties are affected by electrolytic conditions. In general, this cooperation can best be brought about by having the electrolysis survey and the mitigative measures, if any are to be applied, designed and installed under the jurisdiction of a joint committee representing all of the interests concerned or at the discretion of such committee by an engineer employed by the committee, or jointly by the parties to the survey.

II. Electrical Measurements

The electrical measurements to be made during an electrolysis survey may be logically classified in either of two ways, namely, (1) on the basis of the structures on which the measurements are to be made, that is, whether on the railway system, pipe system, or cable system, and (2) on the basis of the character of the measurements, whether of voltage, current on, or current leaving a structure, etc. Inasmuch as several or all of the various types of electrical measurements may at times have to be made on all of the affected structures, and since the methods used will be substantially the same regardless of the utility system to which they apply, it appears most logical to follow the latter classification and discuss the subject from the standpoint of the character of the measurements to be made.

A. VOLTAGE SURVEYS

The number and character of the potential readings required depend on the information desired. As previously pointed out, the readings depend on the thoroughness of the investigation to be made, and it is to be understood that many of the measurements described below would often not be necessary, and in general would be taken only during the course of a complete electrolysis survey. Voltage surveys are here divided into two main classes: (a) Voltage measurements between two points on the same structure, and (b) Measurement of the potential difference between structures.

1. Measurement of Maximum Potential Drop Along Railway Structures.

(a) *Importance of Maximum Potential Drop Measurements.* Such measurements, when interpreted in the light of other conditions to be discussed later, afford a valuable index to electrolysis conditions generally. It is, further, one of the easiest quantities to determine in an electrolysis survey if the use of telephone lines can be secured. These measurements show in general whether the railway system is properly maintained and what lines or sections are most in need of repair and rebonding. When taken in conjunction with the load data, they may be used for an approximate calculation of power losses in the railway return and when studied with due regard to the character and location of railway lines and supply stations, together with the distribution of load, they afford a valuable index as to the need of, or the modification of the track feeder system. It is therefore desirable, as a rule, to take a good many of these measurements as a part of any complete electrolysis survey.

(b) *Procedure in Making Maximum Potential Drop Measurements.* The first step in making measurements of this kind in a city is to determine the location of points between which potentials are to be observed. These usually comprise points on the track most remote from the power supply station as the points of highest potential, and the points on the track nearest the power station as the point of lowest potential. In some cases, however, especially where insulated track feeders are used, the point of lowest potential may be at the point of connection of one of the insulated feeders which may be at a considerable distance from the power station. It is desirable, as a rule, to measure the difference of potential between the points of connection to the tracks of all of the insulated track feeders in order that the points of lowest potential may be determined. It is desirable, as a rule, also to select points intermediate between the points of highest and lowest potential so that the distribution of the potential drop may be determined, as this will give a valuable insight into the location of bad stretches of track and of concentration of return current in the tracks.

Reference should be made to a positive feeder map from which a list of power stations and their approximate feeding distances can be determined. Special lines to these points may be run or spare wires may be borrowed or leased from the telephone company. In the latter case, the continuous cooperation of the telephone company is required. Having a list of points to be reached, the telephone representatives can prepare a table showing the terminal boxes and numbers of spare pairs, including trunk lines which are necessary to make a complete circuit between one of the telephone central offices, or other suitable central point where the measuring instruments are to be placed and the points to which measurements are to be made. All measurements can then be made between the point of lowest potential and all other points selected, and between any two points as desired. Temporary circuits are necessary when no spare telephone conductors are available, in which case working conductors may sometimes be used for short periods. In most cases, it is desirable to make permanent connections to the track for maximum voltage drop measurements, but where, for any reason, permanent or semi-permanent connections to the track cannot be made, temporary connections become necessary and the installation of these temporary connections will require considerable time and expense for labor.

It will be found most convenient to bring all the lines from the various points on the track network to a large board on which is mounted a map of the railway system, each wire being fastened to a binding post located at a point on the map corresponding to the point on the track from which the wire comes. Once the correct connection of wires has been verified, one can readily connect the voltmeter to wires leading to any points in the city without possibility of error.

While making track voltage measurements, and, in fact, all other measurements, it is desirable to arrange to have the test data worked up and tabulated so that it can be carefully studied as the work progresses. This is important because, as pointed out above, the tests to be made during the course of the survey often depend in large measure on the results of preliminary measurements so that by making a study of the preliminary data while the work is in progress, it is often possible to modify original plans in such a way as to greatly increase the value of the test data.

In making electrolysis measurements, it is desirable to take readings at each point over as long a period as practicable. Owing to the great variability of railway loads, it is important to have the readings cover at least one complete cycle of the load, and often several complete cycles are desirable. It is quite common practice to take such readings over a period of one hour, but in some cases, especially on interurban lines and others where the schedule is very infrequent, still longer periods may be necessary. Even where readings are taken over one hour it will generally be necessary for comparative purposes to reduce these readings to an equivalent twenty-four-hour value, and in some cases also corrections have to be made for seasonal changes of the load. This matter will be treated at some length under the discussion of the interpretation of electrolysis survey data.

2. Potential Gradient Measurements.

(a) *Scope of Term.* Under the head of potential gradients will be included all potential measurements between different points on the track or between different points in the earth spaced materially less than the extreme feeding distances within the powerhouse areas.

(b) *Measurement of Potential Gradients in Tracks.* Potential gradient measurements are usually made on the railway tracks, but at times also on pipe systems or even in the earth. The procedure will vary considerably because of the variability of the distances over which measurements are to be made. If the spans are long, telephone wires are the most convenient and the measurements are made in the same way as track voltage measurements described above. Where the distances are relatively short, however, as for example, a few hundred feet or less, a temporary wire between the two points of measurement will usually be most convenient. Connections to the system on which measurements are made will depend on whether the tests are being made between points on the tracks or on the pipe system or between points in the earth. For measurements between points on the tracks or on the pipe system or other metallic structure metallic terminals may be firmly held against the rail or pipe or a wire may be swedged in a slot sawed in the pipe or rail under test. It is sometimes desirable to make potential measurements directly between two points in the earth, though the most common practice has been to take them on the track network. Special situations may arise where potential measurements between various points in the earth are more valuable than those taken on the underground structures. For example, the presence and direction of large transverse currents in the vicinity of important mains can be determined. Buried pipe lines or other conductors at uncertain locations which are discharging current into the earth may be located approximately by earth gradient measurements, there being a reversal or abrupt change in the gradient when the conductor is crossed.

In making earth gradient measurements between points relatively close together, it is essential that a pair of non-polarizable electrodes be used if a high degree of accuracy is to be attained. Such electrodes are now in process of development at the Bureau of Standards.

The periods over which gradient measurements should be made and the procedure in working up the data during the progress of the survey are governed by the same considerations as discussed above in the treatment of the track voltage measurements.

3. Measurement of Potential Differences.

(a) *Purpose of Measurement of Potential Differences.* Measurement of potential differences are beyond question the measurements most frequently made in connection with electrolysis tests and when their limitations are properly taken into account, they afford a valuable index to electrolysis conditions. It should be emphasized, however, that they are chiefly of qualitative significance, being valuable for indicating the region in which more or less damage to pipes may be in progress, but not giving any definite information as to the rate at which injury to pipes may be progressing. This is due to the fact that the resistivity of the earth and railway roadbed varies with local conditions, that is, a given potential difference that would be practically safe under some conditions of soil resistance would be extremely hazardous in other locations. If this factor is properly taken into account, potential difference measurements may be of considerable value in determining electrolysis conditions.

(b) *Procedure in Making Measurements of Potential Differences.* Measurements of potential differences between adjacent structures should be made at many points between fire hydrants, lamp posts or gas or water services and tracks, lead cable sheaths and tracks, lead cables and accessible portions of pipe systems, between any two pipe systems that approach closely to each other, and where practicable between cable systems and the earth. In making contacts on fire hydrants and lamp posts, care should be taken to make contact with the pipe itself, rather than the housing. These measurements, between cable systems and earth, if properly taken, afford the most valuable index of electrolysis conditions, but, unfortunately, they are the most difficult to secure and, unless taken by a competent engineer, thoroughly familiar with the possible sources of error involved, they may be worthless or actually misleading. These measurements when taken should be made throughout a large part of the piping or cable networks, including any regions in which there is reason to believe that stray current may be leaving the affected structures for the earth.

Since the structures between which potential difference measurements are made are usually close together, short leads only are required, short lengths of lamp cord or other flexible wire being most commonly used. Either temporary or more or less permanent connections to metallic structures may be made, according to whether readings are to be taken over a short or long period and whether they are to be repeated at some future time. When measuring potential differences between pipe or cable systems and the earth, it is important to use an auxiliary earth electrode that is known to give a very small galvanic potential against the metal of the structure under test. For lead cables a piece of lead sheath is entirely satisfactory. In the case of iron pipes the problem is more difficult because of the variability of iron and the possibility of complication due to oxidation of either the pipe under test or the auxiliary iron electrode. When such readings with iron electrodes amount to only a few tenths of a volt they should not be regarded as reliable unless taken over a period including that during which the railway power station is shut down, owing to the possibility of galvanic voltages being of this order of magnitude.

B. CURRENT SURVEYS

1. Scope and Importance of Current Measurements

Under the head of current measurements are included all observations of current flow obtained by ammeter readings, or by a potential drop on a conductor, the resistance of which is approximately known. They include measurements of current flowing from subsurface structures into the earth.

Current measurements on undrained structures made both before and after a change in the railway system or the application of other mitigative measures afford considerable information as to the change in electrolysis conditions. Owing to the great variety of conditions under which it is at times necessary to measure current, as in copper feeders, rails, pipes, cable sheaths, and even in portions of the soil, the methods of procedure may vary considerably.

2. Measurement of Currents in Feeders and Rails.

(a) *Purpose of Measuring Feeder and Rail Currents.* Measurements of current in track feeders and rails are usually made only when it is desired to check the current distribution in a network of tracks. Current measurements on the track will show the points at which additional track feeders are required in order to limit potential gradients in the track as well as the amount of current that must be taken off at each point, and consequently the sizes of feeders required. The same result can be obtained with sufficient accuracy for most practical purposes by the use of a "spot map" on which are shown the average distribution of cars and their corresponding loads. Further, by measuring current in different rails in the track, local bad bonding will be revealed, since unequal distribution of current always indicates relatively high resistance in the rails carrying the lower currents. In fact, some engineers regard the measurement of the relative current in the rails at a number of points as the most reliable way of obtaining in a short time a good idea of the condition of track bonding.

(b) *Procedure in Measuring Current in Feeders and Rails.* The most accurate method of measuring current in a feeder of rail is, of course, afforded by inserting an ammeter shunt directly in series with the feeder or rail under test. However, in practice it often happens that in the case of negative feeders ammeters or shunts are not provided and can be inserted only with difficulty, and in the case of rails this is impracticable. The most common method, therefore, of measuring current in such structures is to measure the potential drop on a known length of cable or rail and to calculate the current from this potential drop and the resistance of the conductor. Such measurements of current can be made on copper cables with high accuracy and on steel rails the results can usually be relied upon to 10 per cent. or better, which is sufficient for practically all purposes. In making the current calculations it is customary to consider the resistivity of the copper at 10.7 ohms per circular mil-foot, and that of steel rails to be 0.0003 ohm per pound-foot, this latter being equivalent to a resistance of 0.000009 ohm for one foot of rail weighing 100 pounds per yard. In practice it may be expected, however, that the resistance per pound-foot may vary between the values of 0.00027 and 0.00033, or about ten per cent. each way from the mean values here given. Table 5 in the appendix will be found convenient for calculating the current in rails of various weights.

3. Measurement of Currents in Pipes and Cable Sheaths.

(a) *Purpose and Importance of Pipe Current Measurements.* The measurement of current in pipes and lead cable sheaths is important for a number of reasons. Heavy currents in pipes are often objected to by owners of pipe networks, particularly gas and oil pipes, owing to the fear that trouble may result from ignition of gas or oil due to arcing when two portions of the pipe network are separated, and also due to arcing between adjacent pipes in confined air spaces such as cellars, where there may be considerable potential differences due to such currents. In some cases, also, excessive heating has resulted, due to the presence of abnormally large currents on small pipes, and the presence of such heavy currents may make it very difficult to prevent local interchange of current between neighboring structures. Heavy currents on lead power cables are also objectionable because the heat generated in the lead sheath may limit considerably the carrying capacity of the conductors within the sheath. In view of these factors, it becomes important to measure currents on pipes and cables in many instances. Relative current measurements on pipe and cable systems made before and after the application of mitigative measures are also valuable as an index of the effectiveness of the mitigative system employed. This is true, however, only when there has been no installation of new drainage connections or changes in existing drainage connections on the affected structures.

(b) *Selection of Points of Measurement.* In general in selecting points for making current measurements, it is desirable to secure some points at which maximum current flow may be anticipated, and also a considerable number of points that may be regarded as representative of conditions generally. As a rule, the maximum current in an undrained pipe network may be expected in pipes extending approximately parallel to the tracks and near the neutral or slightly positive areas. Also numerous cases will usually be found in any network in which one or, at most, a few mains serve as connecting links between local networks, and such mains usually will be found to carry much larger currents than mains forming a portion of the network. On drained pipe systems, the maximum currents will as a rule be found in the pipes extending in all directions from the points at which drainage cables are connected. It is impossible to lay down rules more detailed than the above for the selection of points at which measurements should be made. Experienced judgment should be followed in all cases.

(c) *Methods of Measuring Current Flow in Pipes.* Four general classes of methods of measuring current flow in pipes and other metallic structures have been used. The one that is perhaps the most frequently used is the ordinary drop-in-potential method in which the voltage drop on a measured length of pipe, not including a joint, is taken and the current calculated from this voltage drop and the estimated resistance of the portion of the pipe across which the potential drop is measured. Complete tables for the resistance per unit length of the various sizes and kinds of pipe in common use are given in the appendix. Careful tests made on a great variety of specimens of pipe of different kinds indicate that measurements of this kind can be depended upon to give results accurate to within about 10 per cent. which is ample in most cases encountered in practice.

A second method, used in special cases where greater accuracy than is possible by the drop-in-potential method is necessary, is the method for calibrating the pipe either by sending a known current through it superposed on the railway current already flowing in the pipe, or by shunting through an ammeter, certain portions of the current actually flowing in the pipe. These methods have taken various forms, one of the most important of which is described later.

A third method consists in the use of what is known as a direct current ratio relay in a manner somewhat analogous to the use of a current transformer on alternating current circuits. This is useful only where currents of fifty amperes or more flow on the pipe.

A fourth method consists in surrounding the pipe with an iron ring containing an airgap and providing means for measuring the magnetic flux set up across the airgap by the current in the pipe. Several different methods are available for making these measurements. The last two methods may also be used for calibrating the pipes, thus eliminating in some measure the uncertainty arising from the calculation of the pipe resistance. It is questionable, however, whether in most cases the greater accuracy thus achieved is sufficient to warrant the use of the more complicated methods. There are given below somewhat detailed descriptions of the first two of these methods.

Drop-in-Potential Method. This method consists in connecting potential terminals to a section of pipe a few feet apart and measuring the millivolt drop, and in calculating the current from this millivolt drop and the resistance of the section under test. It is very widely used, and its great simplicity adapts it to work of this kind. This method has the great advantage that it can not only be used with an indicating instrument, but also with a recording instrument unless the currents are very small, and thus not only a permanent graphic record be obtained, but also the average value for a given period can be determined. The tables appended to this report are based on careful measurements made by the Bureau of Standards on several hundred specimens of iron and lead pipes from various sources, and they are accurate enough for all practical purposes.

In using this method it is necessary to make an excavation at the point where the measurement is to be taken and attach two leads to the pipe, preferably as far apart as practicable without including a joint. This connection may be made in numerous ways, but perhaps the best way is to insert at each point a corporation cock in which a rubber-covered wire has been soldered. If the connections are to be permanent, the leads should be brought underground to a point inside the curb and there terminated in an ordinary service box or other suitable receptacle so that they will be protected from traffic but readily accessible for repeating the measurement at any time. One method of making such connections and protecting the leads is shown in Fig. 21, and another which has been very successfully used in paved streets is shown in Fig. 22. It is also important that the junction between wire and corporation cock be protected by painting with a heavy asphalt or similar paint. If the current on the pipe is large enough to be of practical significance it can be read with an ordinary sensitive millivoltmeter either indicating or recording. In special cases where the current is extremely small, only a high sensitivity indicating millivoltmeter or even a portable galvanometer can be used.

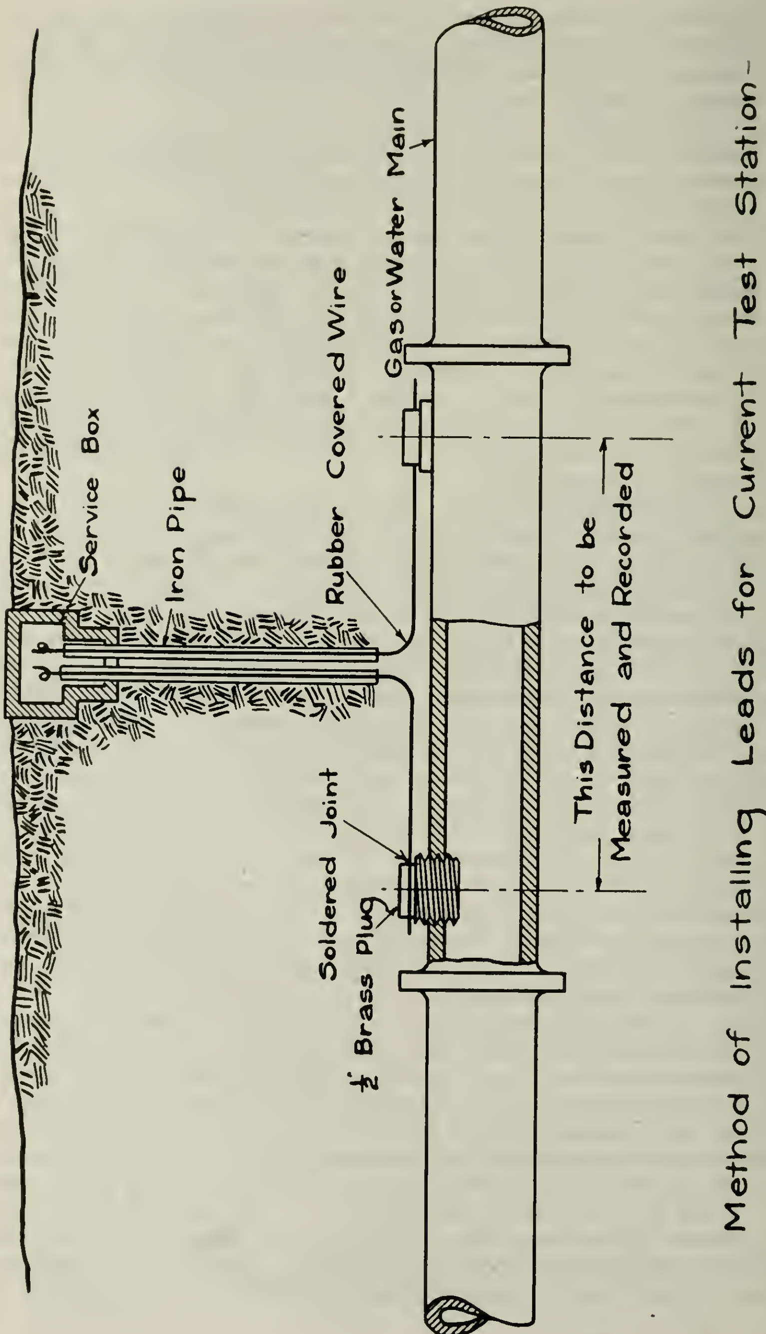

Service Box
Iron Pipe
Rubber Covered Wire
Gas or Water Main
Soldered Joint
½" Brass Plug
This Distance to be Measured and Recorded
Method of Installing Leads for Current Test Station

FIG. 21.

Calibration of Pipes. One of the methods most commonly used for the calibration of pipes involves superposing a current on that already in the pipe and measuring the change in millivolt drop due to this superposed current. This method, originally used by Professor B. F. Thomas, was first described by Dr. Carl Hering in the Transactions of the American Institute of Electrical Engineers for June, 1912. Theoretically, this method should give very high accuracy, but it should be borne in mind that the resistance of the pipe thus determined is correct only for the conditions under which the measurement was made. Iron pipes, especially wrought iron and steel pipes, have a high temperature coefficient of resistance and variations in this resistance due to temperature changes between winter and summer may introduce variations of five per cent or more in this resistance. For this reason it is very doubtful whether the complication involved in the use of this method is justified, but it has been used by some engineers. Further, owing to the presence of rapidly fluctuating railway currents on the pipes, the application of this method is often difficult.

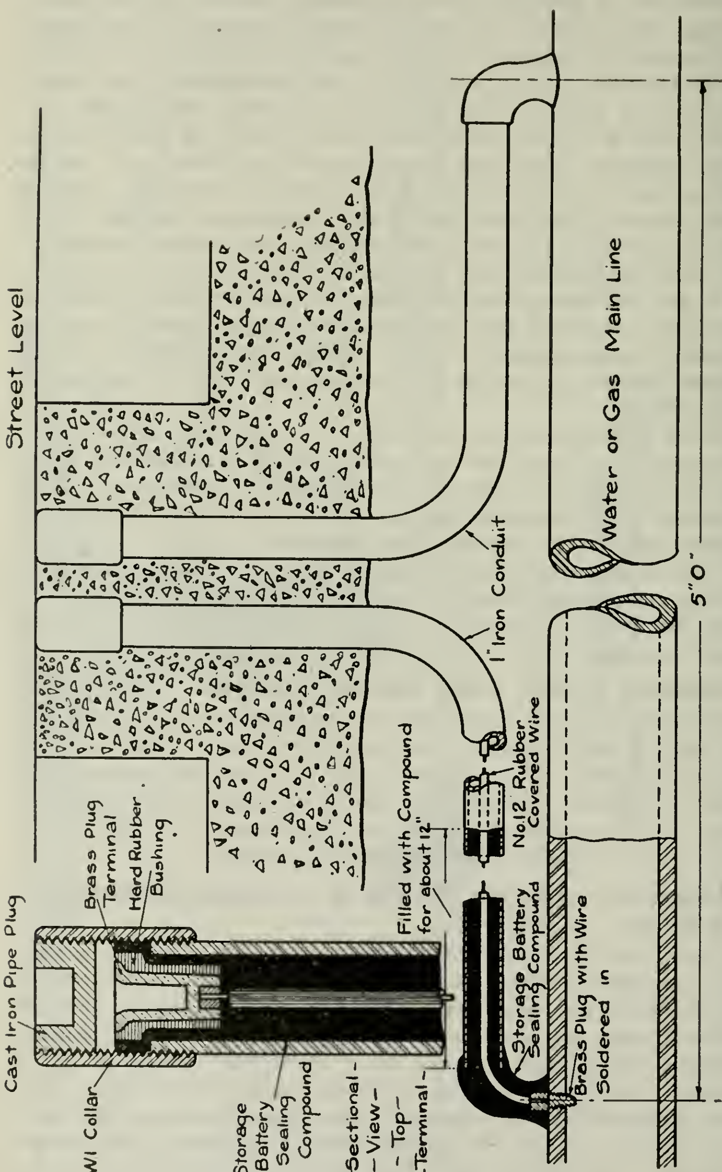
Use of a Direct-Current Ratio Relay. An instrument known as the direct-current ratio relay for measuring current in conductors which cannot be opened for the insertion of ammeters or shunts has recently been devised. The ratio relay permits the measurement of variable unidirectional currents of relatively large magnitude only, on an ordinary direct current ammeter. This instrument gives very good results when very large currents are being measured, but in its present form it is not suitable for measuring currents of a few amperes, such as are most frequently encountered in electrolysis testing.

4. Comparing Currents Under Different Conditions.

In case the object in view is the determination of relative current in pipes under different systems of mitigation, this can be done simply by measuring potential drops between service or between adjacent fire hydrants. In general, the resistance may be regarded as sufficiently constant so that the currents under the two conditions of test will be proportional to the voltages at corresponding test stations.

5. Measurement of Current Flowing from Underground Structures to Earth.

It is extremely desirable to measure the amount of current flowing from a particular portion of a pipe or cable network directly into the earth. In fact, if such measurements could be made conveniently and with sufficient accuracy they would be by far the most important and valuable measurements that could be made in an electrolysis survey, since this measurement would afford the most accurate measure of the rate at which damage is progressing. Unfortunately, there has not been available up to the present time any very satisfactory method of measuring such current flow except in very special cases. Four different methods have been proposed under special conditions for making this measurement. These are: (a) differential current measurements; (b) the use of a Haber earth



- Method of Installing Leads for Current Test Station -

Fig. 22.

current collector; (c) the measurement of polarization potentials; and (d) the combined measurement of potential drop and earth resistivity. The first of these is discussed below. The second and third have been found impractical and the last is still under development.

(a) *Differential Current Measurement.* This method of measuring current flow from a pipe to earth can be used to advantage where it is desired to measure a current discharge that is comparable in magnitude with the total current on the pipe. If the measurement is made at two points on the pipe by the potential drop method, uncertainties in the measured values may be too great to permit an accurate determination of discharge, but if the pipes are carefully calibrated at the points at which the potential drops are measured, fairly accurate results can be obtained, provided the difference in current is as made as ten or fifteen per cent. of the total current flowing in the section of the pipe under test. In making current discharge measurements by this method, it is necessary to make sure that there are no service pipes or drainage feeders connected with the portion of the pipe between test points through which current may flow.

C. MISCELLANEOUS TESTS

1. Track Testing.

Electrical tests are made on railway tracks chiefly for three purposes—first, to locate the cause of bad electrolysis conditions that may have been encountered; second, to serve as a guide for the systematic maintenance of the railway track network; and third, to be used as a guide in designing an electrolysis mitigation system. Three methods of determining the condition of the track system have been extensively used, as follows:

(a) *Inspection.* This method of testing bonds by a simple inspection is one which has been used much more extensively in the past than at the present time, but it is unfortunately still very frequently used in open track work. It consists chiefly in going along the track and making superficial inspection of the bonds and if they appear mechanically good, the assumption is made that the bond is in a satisfactory condition. It cannot be too strongly emphasized that any examination of bonds by this simple method of inspection should be regarded as a poor makeshift, and some more reliable method should always be used.

(b) *Use of Portable Bond Tester.* There are in use at the present time a number of portable bond testers operating on the principle of a slide wire bridge, a portable millivoltmeter being used to determine when the bridge is balanced. In the use of this instrument the voltage drop across the joint is compared directly by the bridge method with the voltage drop on a definite length of rail directly adjacent to the joint under test, so that the resistance of the joint is measured in terms of an equivalent length of rail. This method has the advantage of simplicity as it can be operated by one man, and while somewhat slow and tedious it often affords a very satisfactory method of testing bonds.

(c) *Autographic Method of Bond Testing.* A method that has been used extensively in recent years for testing the bonds in railway tracks is what is known as the autographic method. This method is like that of the portable bond tester in that it is based on a comparison of the potential drop across a certain length of rail, including the joint, with that across an equal length of adjacent solid rail. The two readings are taken and automatically recorded within a fraction of a second, and during this short time the current in the rail may be regarded as practically constant. The method, however, permits of a correction in case the current should vary appreciably betwen two readings. The autographic method has several advantages, chief of which are as follows:

(1) A special test current is employed so that one does not have to depend on the railway load which is uncertain and at times discontinuous.

(2) It eliminates the personal element to a large extent, all readings being autographic.

(3) It gives a permanent record, which can be kept on file for future reference.

(4) A large amount of track can be covered in a short time, so that the test of an entire railway system can quickly be made at any particular period.

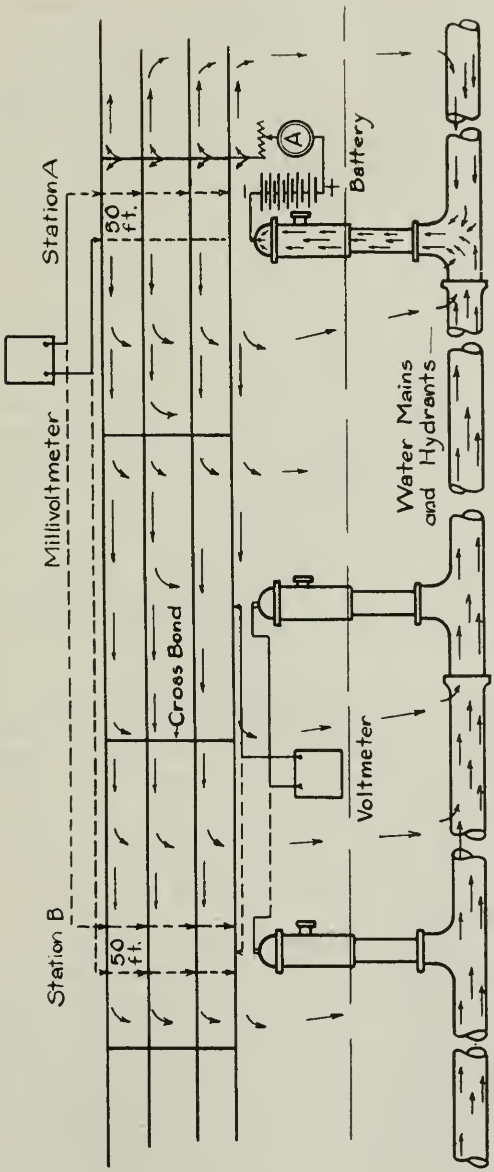
The apparatus for this method of testing is quite expensive, as a special car is required and sometimes another car is used to haul the test car. Owing to the much greater rate at which bonds can be tested by this method, however, the total cost on a large job will not necessarily be greater than with manual testing.

(d) *Testing of Cross-bonds and Special-Work Jumpers.* In addition to testing the joints discussed above, it is important also to test the condition of cross-bonds between rails and of jumpers spanning special work. This can perhaps best be done by means of a low reading voltmeter having two ranges from .01 to one volt, the test being made by going along the track and measuring the potential difference between the various rails at frequent intervals, and also across various sections of special work.

2. Measurement of Leakage Resistance between Tracks and Underground Structures.

(a) *Importance of Tests of Roadbed Resistance.* The determination of the average resistance of the leakage path between railway tracks and surrounding earth is often very desirable, particularly where it is necessary to determine what overall potential drops may safely be permitted in the track return. It will be evident that if the resistance of the leakage paths is very high, it will be safe to allow higher potential drops in the track than if the leakage resistance be low, although the voltage drop which may be considered safe is not directly proportional to the average resistance of the leakage path.

(b) *Differential Method of Measuring Roadbed Resistance.* Fig. 23 illustrates the method employed for making measurements on roadbeds where it is found impracticable to isolate a limited section of the track. After the car traffic has been withdrawn for the night, a portable storage battery is connected, as shown, between the four rails of the track and a fire hydrant on a relatively large main. An ammeter and a regulating



Differential Method of Making Roadbed Resistance Measurements.

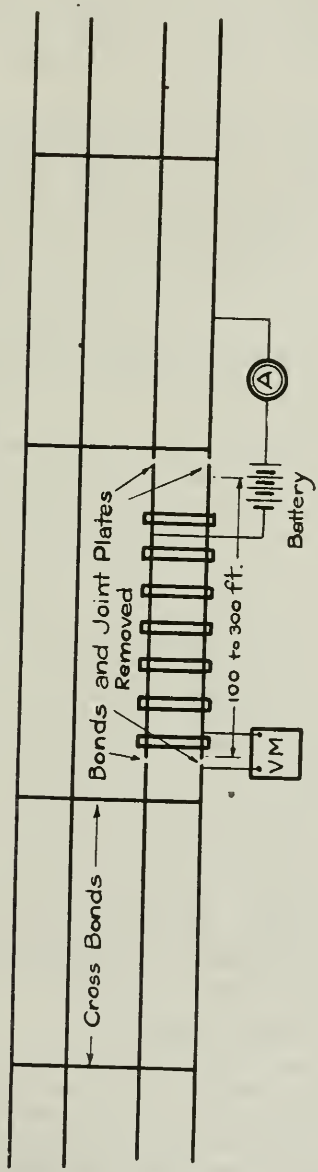
Fig. 23.

resistance are included in the circuit. A ten-volt storage battery or a low voltage generator is employed for this purpose and a constant current of from twenty to forty amperes is maintained during the period of the test. The current entering the rails will flow away from the test station in both directions, as shown by the arrows. Leakage will take place to the earth and all of the current will be picked up by the waterpiping system and returned to the negative pole of the battery. If now a millivoltmeter be employed to measure the potential drop on a short section of the track at Station A, and again at several thousand feet distant at Station B, the loss of current from the rails between the two stations can at once be determined, provided the rails are of the same weight and resistivity at the two stations, and provided further, that the battery current has remained constant. Now, if the potential difference between the section of track under test and the earth at some distance from it be measured, the resistance to earth of this section of track can easily be computed.

While the principle involved in such a measurement is extremely simple, the practical difficulties encountered make accurate and reliable results very difficult of attainment, and it is only by many and repeated measurements that reliable data can be secured. The difference between the currents at stations A and B is the quantity which must be determined, and as this is usually a small fraction of the total current, even over a distance of one-half mile, a slight error in the measurements would be exaggerated in the result. Errors might result from inaccurate readings or from different rail weights or resistivities. It is necessary, therefore, to make not only one measurement on each of the four rails at both stations, but measurements should be made at several slightly different locations at each station.

In determining the average potential difference between the track and the earth, voltage measurements should be made to as many different underground structures as can be found in the vicinity. Measurements made to the fire hydrants along the track are likely to give erroneous results, due to the gradient on the water main caused by the return current. The most reliable and consistent results are obtained by driving a ground rod into the earth at a distance of not less than 200 feet from the track and measuring the potential difference between it and the track with a high resistance voltmeter.

(c) *Isolation Method of Measuring Roadbed Resistance.* When it is desired to make measurements in localities where no piping systems exist, the method just described cannot be employed. These roadbeds are usually of open construction and it is therefore a comparatively simple matter to remove the joint plates and bonds from four joints, thus isolating a section of track on which accurate and reliable measurements can be made. Fig. 24 shows the arrangement of the apparatus for this test. A section of track from 100 to 500 feet in length is isolated from the remainder of the track network by removing the bonds and joint plates as shown. All cross bonds between this test section and the adjacent track must also be cut. A battery of three or four dry cells is connected between the test section and the remainder of the track network, which, being of great



Method of Making Roadbed Resistance Measurements on Open Track Construction.

Fig. 24.

extent, is considered as a remote ground of negligible resistance. A low-reading ammeter and a voltmeter give the current flowing and the potential difference between the section of the track under test and the remote ground, and from these data the resistance to earth is easily and accurately calculated.

By taking several hundred feet of track, the effect of the short leakage paths at the ends of the section is practically eliminated.

The resistance so found is for a single-track roadbed, but in the open type of construction the resistance to earth is concentrated largely in the ties and therefore the resistance of double track can be taken as one-half that of single track. This is not true when the rails are imbedded in earth or concrete. In this case the resistance of a double track may be taken as about seventy per cent of that of a single track if only approximate results are required. This method of measuring roadbed resistance necessitates working at night, as does the differential method, since it usually requires several hours to remove and replace the bonds and joint plates on four joints.

3. Location and Testing of High-Resistance Joints in Pipes.

In making electrolysis surveys it is often necessary to determine whether or not there are any considerable number of high resistance joints in a given portion of a pipe network. This has been a particularly important test in making investigations of joint electrolysis in pipe systems, and may often be useful in determining upon the method of protection to be used in particular cases. High resistance joints may be most conveniently located by means of potential drop measurements along the pipes. The method usually followed is to drive bars down until they come in contact with the pipe and measure the potential drop on the pipe at such points, the spacing of the points being usually about 100 feet. A series of such measurements is made throughout the entire length of the pipe and the relative magnitudes of the voltage drops on adjacent sections would indicate which, if any, is affected by high resistance in the pipe line. When it has been determined that any particular hundred-foot length includes one or more high resistance joints, this section can be further subdivided by exactly the same procedure until a relatively high drop is obtained between two points less than a pipe length apart, which must include a high resistance joint. By comparing the drop across the high resistance joint with the drop in a measured distance on continuous pipe, the resistance of the joint in terms of equivalent feet of pipe can be obtained.

4. Tracing the Source of Stray Currents.

Conditions are often encountered in which stray currents on pipe networks may come from any one of two or more railway lines, and it is important to determine from which line the current is derived. This can be determined in either of two ways. One method is to connect a measuring instrument of the recording type to the pipe under test, which may be connected either to indicate the current flow along the pipe or the potential difference between the pipe and the earth. With the instrument thus connected, a record is obtained, while all railway systems are operating under normal conditions. Then one of the railway systems is shut down for as long a period as practicable. If the shutting down of the plant makes a marked difference in the record, it is an indication that a large part of the stray current at least comes from that particular point. By shutting down the different systems in rotation, a fairly definite knowledge of the source of the stray current may be obtained. Sometimes it will be found that the shutting down of one plant increases the current flow in one direction, while shutting down another plant may give rise to a large current flow in the opposite direction, both currents being larger than when both plants are running. This will indicate that the stray current from the two systems tend to neutralize each other, thus giving rise to better conditions in certain localities than those which prevail when either system is operating alone.

The other method of tracing the source of stray current in any particular case consists in the use of two or more recorders, one of which makes a graphic record of the current or voltage, the source of which is to be determined, while the others are used to make simultaneous records of the loads on the various power supply stations which may possibly affect the area in question, or more particularly the loads on certain feeders from those stations. In most cases there will be sufficient similarity between the chart of the stray current and some one of the feeder or station load charts to establish quite definitely the source of the stray current.

5. Location of Unknown Metallic Structures or Connections.

It is often desirable to locate metallic connections between pipes and various other structures, such as railway track returns which may often exist without the knowledge of either the pipe or railway company. Two methods are available for doing this: One consists in connecting an external electrical circuit between convenient points on the pipe system and the railway system, and sending between them either an alternating current of audible frequency or a direct current interrupted at audible frequency. An exploring coil is then carried along the pipe system in such position that the alternating or pulsating magnetic field produced by the current superposed on the pipe current will induce an electromotive force in the coil. This can be made audible by the use of a telephone receiver. By this instrument, the path of the current can be traced and in most cases the location of concealed connections to the pipe can be determined. The method works very satisfactorily on relatively simple pipe networks, but in very complicated systems where there are a great many pipes laid in the street it becomes relatively difficult to trace out any particular structure.

A method that has been more recently developed and which is considerably more simple than the above, consists in doing away with the additional current superposed on the pipe network, and using the exploring coil and telephone to listen to the commutation not in the railway current carried by the pipe. This method is much to be preferred where the pipe currents are large enough to give sufficient sensitivity. In some cases, however, where the currents on the pipe are very small, the first method may have to be resorted to.

III. Interpretation of Results of Electrolysis Surveys

No definite rules of procedure can be laid down for the interpretation of the results of electrolysis surveys that can be used except by engineers thoroughly familiar with all the factors involved. The significance of any particular set of readings is so dependent upon other conditions that all factors must be taken into account or else the conclusions are likely to be in error. However, it is desirable to point out certain principles that must be kept in mind even by the experienced engineer in order to arrive at correct conclusions.

A. INTERPRETATION OF POTENTIAL MEASUREMENTS

1. Maximum Voltages and Track Gradients.

These measurements, when considered in the light of a full knowledge of all conditions, give valuable data on the condition of the railway track system and the concentration of return current on certain sections of track. They also are valuable when considered in the light of the load on the different lines, as they offer a fairly accurate indication of the track losses and the necessity for the use of additional track feeders. When such potential measurements are taken over relatively short lengths of track, such as 1,000 or 2,000 feet, the comparison of such measurements on adjacent sections of track will often reveal bad places in the track that are in need of rebonding.

2. Potential Difference Measurements.

Potential difference readings between pipes and railway tracks and between various underground structures are not a quantitative measure of the danger to the affected structures. These readings are valuable in pointing out the general areas in which trouble may be expected to occur and in which more careful search may be made if desired. They are, however, of qualitative significance only. The current leaving a structure for the earth in any locality, which is the real cause of the electrolysis damage, is a function not only of the potential differences but of the resistance of the earth paths. This has been shown to vary throughout extremely wide limits, so that the measurement of potential difference gives no definite quantitative measurement of the extent of the hazard to the pipes. Such measurements are very valuable and have an accurate quantitative significance, however, when used to determine the relative electrolysis conditions under different systems of mitigation. If, for example, under a given set of conditions a considerable number of potential difference measurements are made between the various underground structures and then a change is made in the mitigative system, and the same measurements repeated, the two sets of readings may be used to represent the comparative hazard in the two cases. This is true only if the mitigative measures under test are applied exclusively to the railway return system.

High potential differences between gas and oil pipes and other metallic structures with which they may come in contact are objectionable especially in confined spaces, such as basements in which explosive mixtures may be encountered. This is because a transient contact between the two structures may cause an arc which may result in fire or explosion.

B. INTERPRETATION OF CURRENT MEASUREMENTS ON UNDERGROUND STRUCTURES

1. Relation of Stray Current to Corrosion.

The magnitude of the current on an underground structure does not alone afford a measure of the total injury to the structure. If all the current that flows on the pipe is discharged directly into the earth, then the total corrosion will be approximately proportional to the current flow. Even here, however, the rate of damage to the pipes is not only a function of the total weight of metal corroded away, but of the distribution of such corrosion as a result of pitting or of localized discharge from one system to another where they approach close to each other. Further, if there are metallic connections either known or unknown between portions of the pipe networks and the railway tracks, which carry off a large part of the current on the pipe through metallic paths, the total amount of corrosion cannot be determined by measurement of the current flow. For this reason current measurements on pipes should likewise be regarded as having only a qualitative significance in so far as any absolute hazard to the pipes is concerned. If, however, the pipes have no drainage connection and changes are made in the railway track network, the corresponding changes in the currents on the pipes may, if a sufficient number of readings have been taken, indicate the relative improvement in the electrolysis conditions.

2. Relation of Current to Fires and Explosions.

In interpreting the significance of current measurements on gas or oil pipes, due account should be taken of the possibility of fires and explosions due to arcs formed either when pipes are disconnected, or when pipes make transient contact in confined places such as cellars. No definite information is at present available as to what limiting currents on such pipes may be considered safe, but it is generally recognized that the presence of currents on gas and oil lines is more objectionable than in the case of other pipes.

C. INTERPRETATION OF MEASUREMENTS OF CURRENT FLOWING FROM STRUCTURES TO EARTH

The only accurate criterion of electrolysis damage is the intensity of current flow to earth at any point on the pipe or cable. If an accurate measure of this current flow from the pipe at any point could be made, it would come nearer giving a true indication of electrolysis conditions than any other measurement. At the present time there is no practical means available for making such measurements. The development of a simple, inexpensive and accurate means for measuring such currents locally, constitutes one of the chief needs in the field of electrolysis testing at the present time.

D. USE OF REDUCTION FACTORS

In many cases it is not practicable to take readings of current and potential at any point over a sufficiently long time to get all day average values of the readings at that point. Such readings should always be taken for as long a time as circumstances permit, but in making electrolysis surveys, it is usually necessary to take a large number of readings scattered over a wide area so that some of the readings can be continued only for a comparatively short time. Such short-time readings cannot, in general, be used directly as a basis for determining electrolysis conditions and in order to interpret properly the results of the survey, the readings must be reduced to some common basis, as, for example, either the twenty-four-hour average, the operating-day average, or the average for the hour of the peak load. Each of these bases has certain advantages and disadvantages depending partly on the individual conditions, and the method of procedure will often differ, depending on the method to be followed in interpreting the results. All are affected by such factors as rush or light days, unusual weather conditions, electric heaters in cold weather, morning and evening peak loads, and other causes, and these factors must be considered.

The great unreliability of short-time readings for determining electrolysis conditions is especially noticeable when comparing the load curve of a line having a 5, 10 or 15 minute schedule with that of hourly interurban service, or when comparing that of a station having a 45 per cent. load factor with one having a load factor of 10 per cent. Because of this great variation and uncertainity in short time measurements and for the purposes of interpretation and comparison, it is desirable that long time readings be obtained, but if this is impossible, all short-time readings should be reduced to values for some representative period, preferably the twenty-four-hour average.

Experience shows that in the majority of cases, short-time readings of from 15 minutes to an hour, taken on a city network between the hours of 10 a. m. and about 4 p. m., approach rather closely the twenty-four-hour average values, and it is found permissible to neglect the use of reduction factors in connection with readings taken during this period of the day. When, however, readings are taken at any time during the morning or evening peak, or after nine or ten o'clock at night, it is necessary to use a proper reduction factor if anything like reliable conclusions are to be reached. In general, it seems preferable to reduce such readings to the all-day average basis, rather than to the operating-day average since the operating day varies in length in different cities.

E. EFFECT OF REVERSALS OF POLARITY

Throughout a large portion of the territory served by a grounded railway system, it will be found that the potential differences between pipes and earth frequently reverse in direction, the pipes becoming alternately positive and negative to earth with periods varying from a few seconds to several minutes or even longer; and special consideration has to be given to measurements in such places in order that even an approximate estimate of their significance can be made. In general, four different classes of conditions have to be recognized in interpreting these measurements as follows:

1. Polarity of Pipes Always the Same.

If the pipes are always of the same polarity, as, for example, always positive to surrounding structures, it is, of course, the arithmetical average value that should be used in judging the significance of the readings.

2. Polarity of Pipes Changing with Long Periods of Several Hours.

If the pipes at any point are continuously positive for a period of several hours, and then of opposite polarity for a succeeding period of some hours, a condition which frequently exists in localities where a substation is operated during only a portion of the day, there will, in general, be relatively very little protective effect due to the period when the pipe is negative or neutral to earth, and the actual corrosion is most nearly indicated by the arithmetical average value of the voltage or currents during the hours in which the pipe is positive to earth, this average, of course, being reduced to the twenty-four-hour average basis. Thus, if a given pipe is found to be positive to the earth or other neighboring structures by a given amount for a period of twelve hours, and either negative or at zero potential for the remaining twelve hours of the day, the actual amount of corrosion that would occur would undoubtedly be nearly equivalent to that which would result if the potential at the same point was maintained half as great for the full twenty-four hours.

3. Polarity of Pipes Reversing with Periods of Only a Few Minutes.

Where the polarity of the pipes reverses with a period of only a few minutes, it has been shown by extensive experiments that the corrosive process is in large measure reversible, and the actual amount of corrosion comes more nearly being proportional to the algebraic average of the applied potential than it is to the arithmetical average during the total time the pipe is positive. In all cases, therefore, where the polarity of the pipe is continuously reversing and the period of reversal does not exceed five or ten minutes, the algebraic average of the voltages or currents should be given far greater weight than the arithmetical average values during the positive period.

4. Polarity of Pipes Reversing with Periods of From Fifteen Minutes to One Hour.

Under these conditions, neither the algebraic nor the arithmetical average of the applied potential or current flow gives an accurate index of the amount of corrosion. For the shorter period the algebraic average comes more nearly being the proper criterion, while as the period increases in length the arithmetical average tends to give a better indication of the extent of the resulting corrosion. However, even where the period of reversal is as long as one hour, the corrosive process is, under most conditions, to a considerable extent reversible and some allowance in interpreting the results should be made.

IV. SELECTION OF INSTRUMENTS

In this section descriptions are given of the apparatus and tools which are essentially special for electrolysis work. The tools ordinarily used for handling wires and making good contacts in electrical work will also be needed, but no special description or listing of them seems to be necessary in this place.

A. PORTABLE MEASURING INSTRUMENTS

The portable measuring instruments required in electrolysis survey work include voltmeters, millivoltmeters, and ammeters. Separate instruments of each kind can, of course, be carried, but it will usually be found more convenient to employ the special portable instruments which have been designed particularly for this work. Three such instruments which the Weston Electrical Instrument Company manufacture for this class of work are as follows:

Model 1, combination millivoltmeter and voltmeter, has its zero in the center of the scale, and reads in both directions. Ranges of 5, 50, and 500 millivolts and of 5 and 10 volts are convenient. It is made with a specially high resistance of from 500 to 600 ohms per volt so that the 5 millivolt range has a resistance of about 3 ohms. These high resistances minimize errors due to resistances of leads or contacts. For work on the street, a dust-proof case should be specified. Ordinary switchboard shunts provided with binding posts and adjusted for 50 millivolts may be used to make this instrument serve as an ammeter. Convenient ranges for these shunts in electrolysis work are 5, 50, and 500 amperes.

Model 56, combination volt-ammeter, has its zero in the center of the scale and reads in both directions. Ranges of 10, 50, and 500 millivolts, 5 and 50 volts and up to 100 amperes are convenient.

Model 322, millivoltmeter, has the zero at the left of the scale and a full scale deflection of one millivolt. Owing to the low range and extremely light movement it must be used with a great deal of care. It is useful for determining very low differences of potential such as drops along short sections of pipe or feeder for determining current flow.

The center scale feature referred to in the description of these instruments is an important one in electrolysis work, as it is not always possible to determine in advance the direction of current or potential, and readings may also vary from positive to negative values during the making of observations at many testing points. When simultaneous readings have to be taken at two or more testing points, it is important to use similar instruments at all points. If dissimilar instruments are used, their periods may differ and with the fluctuating voltages and currents encountered in much of this work, accurate simultaneous measurements cannot be made unless the instruments used have the same periods.

B. RECORDING INSTRUMENTS

Recording measuring instruments are usally arranged to give 24-hour records without change of chart. By using a sensitive millivoltmeter in the recording instrument and providing it with a number of voltage ranges as well as with suitable shunts, a single instrument can be made available for taking all of the voltage and current readings required in electrolysis work. The type of Bristol recording instruments used for electrolysis work makes a record upon a smoke-chart which has to be treated subsequently with a fixative supplied with the instrument. The Bristol instruments are regularly made with a clock supplied with a changing lever so that the disk can be made to rotate either in one hour or twenty-four hours.

The Esterline recorder uses ink and a roll chart and may be obtained with a large range in chart speeds. This is particularly valuable in the detailed study of changes which take place during short intervals and where a record covering more than one day is required. The clock will operate for a week with one winding. Several other manufacturers make portable recorders suitable for some electrolysis measurements. In either type of instrument, center scale zeros should be called for so that variations between positive and negative values will be recorded on the chart.

V. RECORDS AND REPORTS

A. GENERAL DISCUSSION

Much detailed information is necessarily gathered in the course of an electrolysis survey. It is desirable to prepare in advance of the work for the convenient recording of these data upon suitably arranged testing sheets, which either have upon one line or upon one sheet, as may be necessary, all of the data collected at any stated testing point during a single period of observation. Several typical data sheets prepared for recording observations made upon piping and cable systems are given in the appendix to this report as suggestive of possible arrangements for report sheets. The data thus collected can usually be best arranged for study if they are transferred to a map showing the system or systems included in the tests, and indicated thereon either in numerical form or through some graphical representation. It is desirable to indicate positive and negative relations by making records on the maps in different colors.

Apart from the data obtained through observations in the work of the electrolysis survey, the records obtained relating to the systems under observaton should include the following:

B. ELECTRIC RAILWAYS

1. Maps showing locations of sources of power supply, tracks and negative feeders and other connections between busbar and track; also locations of positive feeding connections to trolley and all trolley feeder sections.

2. Information regarding magnitude and distribution of load shown by a "spot map" of the railway system.

3. Information as to size of rails, methods of bonding and standards of bond maintenance.

4. Information as to any direct ground connections applied to the railway return system, and any special track features which may affect the flow of stray currents.

C. PIPING SYSTEMS

1. Maps showing all main pipe lines and branches (except service connections) and sources of water, gas, etc., from which the piping systems are supplied.

2. Information as to sizes of pipes, and metals of which they are composed, and details of the standard methods of joining main and branch line pipe sections.

3. Information as to method of joining service connections to main supply pipes including metals used for the building connection pipes and the depth to which such connections are buried.

4. Location and description of any protective devices such as insulating joints; also any drainage connections which may have been made a part of the piping system.

5. Information as to methods of attachment and construction employed in carrying pipes over highway or railway bridges or under water courses, swamps, etc.

D. CABLE SYSTEMS

1. Maps showing locations of all conduit routes and giving number and sizes of cables in place therein or the total cross-section of lead sheaths expressed in equivalent copper, also locations of power stations, substations or other centers from which cables radiate. Complete data on bonding practice should be secured.

2. Locations, routes and sizes of all drainage connections attached to cable systems, also locations of all insulating joints in cable systems, of any jumpers which may be run to establish a metallic circuit across an insulated gap in the cable system and of any conductors run to reinforce the carrying capacity of the cable system for stray currents.

3. Information as to methods of attachment and construction employed in carrying cables over highway or railway bridges or under water courses, swamps, etc.

E. BRIDGES AND BUILDINGS

1. Locations of structures with respect to electric railways.

2. Information as to methods of construction employed in carrying electric railways, pipes and cables across bridges and particularly as to whether any of these other structural systems make electrical contact with the metal structure of the bridge.

F. GENERAL CONDITIONS

1. Maps showing locations of water courses, swamps, and other features tending to produce locally, earth of high unit conductivity.

2. Records of electrical resistance of soil samples representative of the area.

3. Records of experience obtained in the use of different metals for pipes, etc., in the soils of the area.

It is desirable that in the preparation of records and of reports, consideration be given to the necessity of their perpetuation. All records which will be of permanent value of connection with the continued study of electrolysis conditions in any particular area in order to make sure that injurious changes in conditions do not occur, should be prepared in a permanent form capable of withstanding considerable handling.

VI. TABLES

The tables in the appendix are to be used for calculating the current flow in different kinds and sizes of pipes from the measurement of the millivolt drop on a definite length of pipe. These tables were prepared by the U. S. Bureau of Standards from a large amount of test data taken on representative specimens of pipe from a number of different manufacturers.

The figures for wrought iron pipes represent the result of tests made on 86 separate specimens of pipe. Those for steel pipe are based on tests of 64 specimens, and those for cast iron are based on test data from 22 speciments of pipe from a number of different foundries.

The tables for lead pipe are based on test data taken on 27 specimens ranging from one-fourth to two inches in diameter, all of which, however, were obtained from one manufacturer. It is believed, however, that these figures can be used for all lead service pipes with sufficient accuracy for most practical purposes.

These tests showed that the resistance of cast iron, wrought iron, and steel pipes can be estimated from these tables with an accuracy of at least 10 per cent., and in most cases the results will be even better than this. The tests showed an average resistivity for steel pipe of 215.8 microhms per pound-foot, for wrought iron pipe 209.3 microhms per pound-foot, and for cast iron the figures is 1,227 microhms per pound-foot. These average values have been used in the calculation of the tables.

Tables for lead sheathed cables have not been included in this report, owing to the large number of different sizes and thicknesses of sheaths used for signal and power cables, as well as a variation in resistivity with different sheath compositions.

Chapter 4

EUROPEAN PRACTICE

A. GENERAL

In the study of the practice followed in European countries for handling the problem of electrolysis, it has appeared impossible to secure reliable and satisfactory information merely by correspondence and consultation of published reports and regulations. Moreover, the several independent reports made by American investigators before the foundation of the American Committee, were made from the standpoint of some special industry rather than from the broad and comprehensive viewpoint of this Committee. Under these circumstances the necessity for an independent personal investigation was evident.

The Chairman of this Sub-Committee, after consultation with its members and with the general Chairman, decided to visit several European countries during the summer of 1914. Information concerning important foreign cities and authorities, and papers, suggestions and references were obtained from Mr. H. S. Warren and the late Prof. Albert F. Ganz. Also the officials of the Bureau of Standards were consulted when the field of inquiry and special points to be looked after were carefully discussed. An effort to have the Bureau of Standards appoint a representative to join the party failed on account of their extensive engagements. However, the party included an engineer thoroughly conversant with electrolysis measurements and surveys.

The visiting Commitee spent June and July in its investigation, covering Germany, Italy, France, and England. In each country an effort was made to take measurements and to collect data and surveys, also to interview the most prominent people in each of the different interests affected by the problem of electrolysis. In each case extended conferences were held with the engineers most familiar with the problem and its details, either in their capacity of specialized consulting engineers, or as officials of corporations or public authorities directly concerned in the surveys, disputes, or administrative measures relating to electrolysis.

After this investigation of 1914, the conditions which existed during the War and later made it impossible to collect any further information until the winter of 1920-21, and even then only fragmentary reports of later developments were obtained from Great Britain alone. However, it is believed that the same circumstances have retarded development so that the conditions observed in 1914 correspond substantially with those existing at the present time. It should be borne in mind, however, that references in this report to the current status of committees or commissions, and of legislation or litigation, will, unless otherwise noted, refer to the summer of 1914.

The results of the Sub-Committee's investigations are summarized in the paragraphs immediately following, classified by principal topics. This is followed by statistical information, details of design and operation, and rules and regulations in effect in different European countries.

B. LAWS AND REGULATIONS

1. Germany.

There are no laws specifically relating to electrolysis, and so far as could be ascertained, there are no local ordinances dealing with this subject. The common law of most of the states prescribes that all of the conditions under which a corporation is to operate must be contained in the original grant and any later grants for extensions. The law requires that due publicity be given to any request for a franchise or for extensions of lines, so as to afford all parties who may be affected an opportunity to place on record any limitation they may desire to propose, or to request provisions concerning possible damage, before the concession is granted to the applicant. Hence, a pipe owning company organized subsequently to the existence of an electric railway is held to have assumed the risks existing at the time of its organization, and it therefore cannot claim damages from this railway on account of electrolysis unless the original franchise to the railway contained a clause regarding such damage.

The foregoing applies to private corporations. Municipal corporations, on the other hand, do not assume the legal obligation to protect existing systems against the effects of electrolysis. In such cases, pipe owning companies already in existence are deprived of the privilege of demanding that protection against possible future damage which would be accorded them in the case of a new privately owned railway company.

Municipalities, however, for their own new railway construction, as well as for new extensions of the railways of private companies, always prescribe that they be constructed and operated in accordance with existing technical standards. The recommendations of the German Earth Current Commission are recognized as the existing technical standards in matters relating to electrolysis and in this manner they have assumed almost the importance of law. These regulations are being generally incorporated in contracts for new enterprises or extensions, and in such cases they do substantially attain the force of law.

(a) *Commission Recommendations.* The work of the German Earth Current Commission is described in detail in another place, and a translation of the complete text of its recommendations is given later. The recommendations of the Commission were adopted by the German Electrotechnical Society in 1910. In abstract the recommendations prescribe the following:

In large cities, and in general in urban networks and for a distance of 2 km. (1.24 miles) beyond, the overall rail drop is limited to 2.5 volts. Outside of this zone, and in general in small places or for single lines, the potential gradient is limited to 1 volt per km. (1.6 volts per mile). Exceptions are made for roads operating only a few hours in the day. Bonds must not increase the resistance of tracks over 20 per cent.; they must be tested yearly, and when a bond shows a resistance higher than ten meters (11 yards) of rail it must be repaired. Connections to pipes are prohibited. Bare return feeders are not allowed. Pilot wires are prescribed. The voltage limits given are interpreted to be the average for the entire daily period of operation, usually 18 to 20 hours in 24 hours. If measurements are not actually taken over the entire period they are corrected to obtain a figure corresponding to this average.

2. Italy.

The Government has not enacted any law affecting the operation of electric railways in relation to electrolysis problems, nor has any municipality issued regulations on the subject.

3. France.

Regulation in France is based on a Ministerial decree of March 21, 1911, establishing the technical conditions which electrical distribution systems must satisfy in order to conform to the Law of June 15, 1906. A translation of the text of this decree is given later. Briefly the requirements are:

That the maximum voltage drop in rail returns of electric tramways shall not exceed one volt per kilometer (1.6 volts per mile) ; an exception is made for locations where metallic masses, such as pipe networks, do not exist. Bonds must be kept in the best possible condition; the resistance of a bond must not be greater than ten meters (11 yards) of normal rail. Return feeders must be insulated. Periodic tests must be made and recorded on a register subject to inspection by the control service.

No definition is given of the time element in the measurement of maximum drop, except that it is stated that it must be the average for the normal schedule.

4. Spain.

A translation of sections of the Law of March 23, 1900, relating to electric railway return circuits is given later. Briefly, this law requires the overall voltage not to exceed seven volts, specifies bonding and cross-bonding, and where necessary reinforcements of rail conductivity.

5. Great Britain.

Control of electrolysis matters in Great Britain is obtained through regulations made by the Board of Trade under the provisions of special Tramways Acts or Light Railway Orders authorizing "lines" on public roads; for regulating the use of electric power; for preventing fusion or injurious electrolytic action of or on gas or water pipes or other metallic pipes, structures, or substances; and for minimizing, as far as it is reasonably practicable, injurious interference with the electric wires, lines, and apparatus of parties other than the railway company, and the current therein, whether such lines do or do not use the earth as a return.

The Board of Trade Regulations were first made in March, 1894; they have been revised from time to time, the last revision having been made in September, 1912. The full text of the Regulations is given in a following section of this report. In abstract, the regulations prescribe that the overall rail drop shall not exceed seven volts, and there are also clauses concerning track leakage, the measurement of these quantities, etc. The regulations also provide for circular returns to be made upon the call of the proper authorities.

The Board of Trade makes inspections on its own initiative because it is responsible for its rules, which have substantially the force of law; it also investigates complaints. There are no regular inspections on account of the lack of a proper appropriation. Most of its information is obtained from the returns; the latest call for a return was issued in 1906.

The overall voltage is defined, in practice, as an average for about twenty minutes at peak load. This "average" is obtained as the mean between the average of the maxima during the period (disregarding unusually high swings) and the actual average of all measurements. This quantity is usually obtained in practice from inspection of recording instrument charts.

There are no local ordinances which have the effect of modifying the Board of Trade Regulations. Pipe owning companies cannot recover damages in case corrosion occurs where the Regulations are complied with. This has led to numerous applications to Parliament for special statutory orders fixing responsibility for damage, or special clauses of like import in Acts granting powers to electric railway undertakings. Most of these have been refused, but some have been granted.

It is generally admitted that the Board of Trade Regulations, as originally drawn, were empirical, and that they might be remodeled with advantage; but since the only form of the regulations actually rigidly enforced, namely, the limit for overall rail drop, results in substantial immunity, the great difficulty attending revision has not seemed to be justified.

Railway electrifications, as distinguished from tramways, do not come under the above regulations unless it is especially provided in the Parliamentary Act authorizing the electrification. Recent advices indicate that railway electrifications generally have not been brought under the Regulations.

C. CONSTRUCTION CHARACTERISTICS

General types of construction for electric railways and pipe or cable systems and special features characterizing such systems in the various countries visited, are summarized here. Details of construction and statistical tables are given in Figs. 25 to 31, and Tables 7 and 8.

1. General.

In large cities the tramways are supplied from a number of sub-stations, as in the municipal system of Glasgow and Manchester. In Berlin, particularly, the railway system is supplied from a great number of combination light and railway sub-stations feeding limited districts entailing relatively small positive line drop of potential. In England, average feeding distances are said to be from two to three miles (3 to 5 km).

The ordinary single overhead trolley with the running rails used as some part of the return circuit is predominantly used in all the countries visited. Special features of the return circuit are discussed under appropriate headings below.

The gas and water piping systems in all of the countries visited did

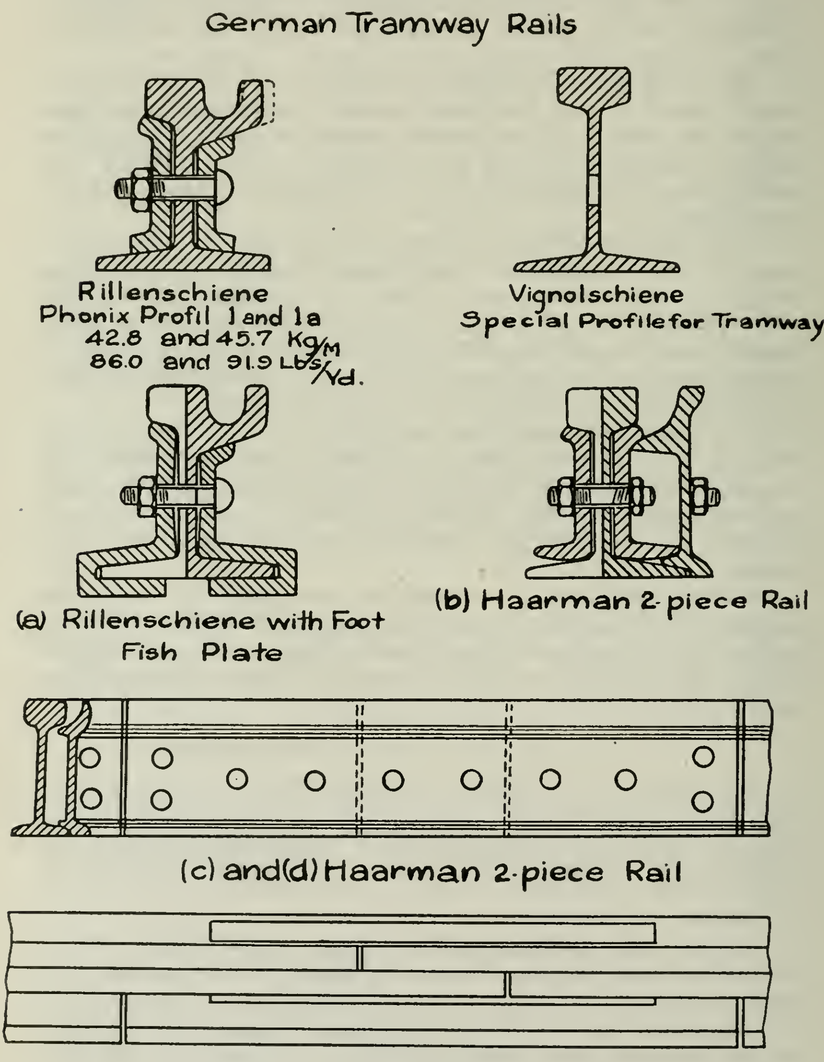


Fig. 25.

not present any features differentiating them from piping systems in America, so far as the electrolysis problem is concerned. In general, pipes are laid in somewhat more shallow trenches than in our northern states, and interconnection between gas and water systems for heating devices seem to be less common than in America.

2. Rails.

In Germany, the common rail weights are 50-60 kg. per meter (101-121

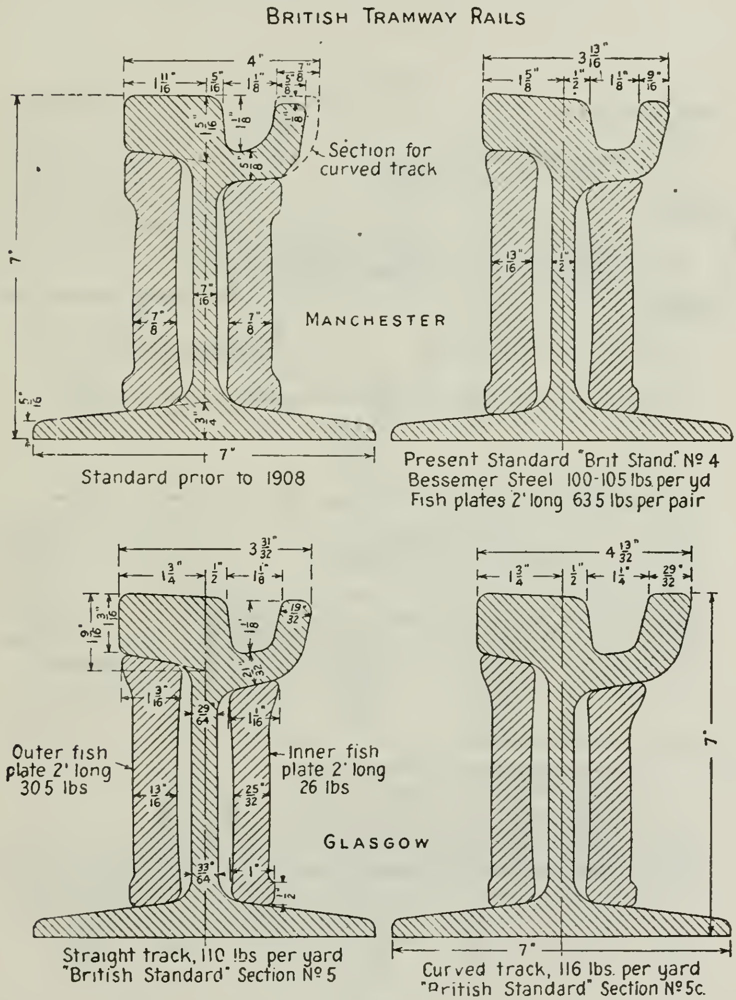


FIG. 26.

lb. per yard) for tramways, and 30-40 kg. per meter (60-81 lb. per yard) for interurban lines. In France the ordinary rail weights are 46 to 51 kg. per meter (93-103 lb. per yard). In England rail weights vary from

70 to 100 lb. per yard (34.7-49.6 kg. per meter) in the majority of cases. (See Figs. 25, 26 and 27.)

3. **Rail Bonds.**

Solid copper pin type bonds, usually 1 meter (3.3 ft.) long, are most

RAIL WEIGHT DATA

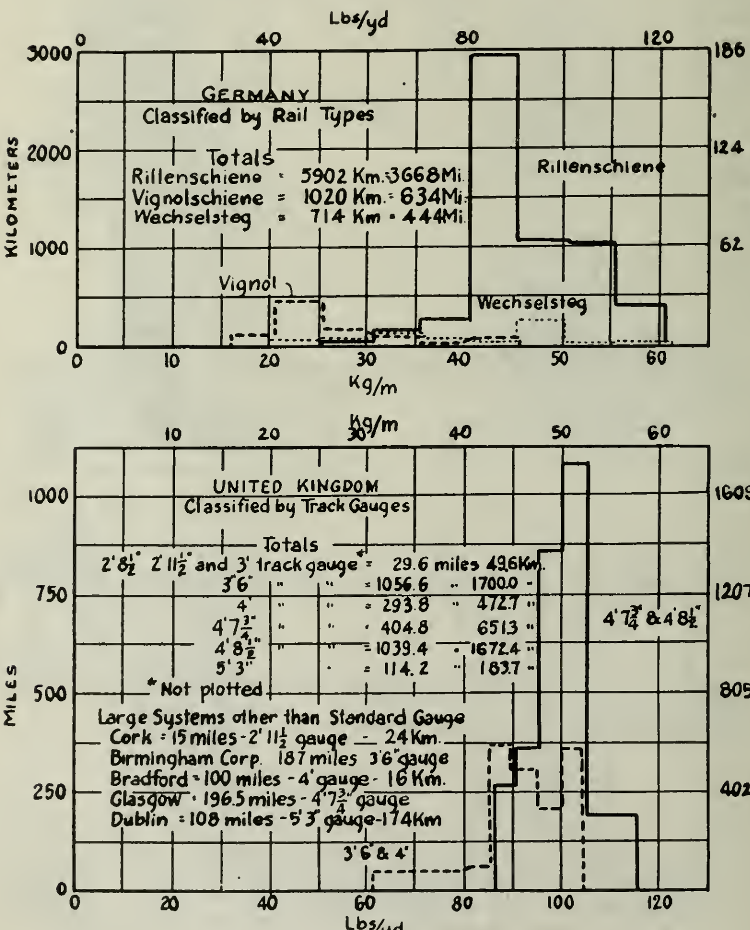


FIG. 27.

commonly used in Germany and France. The Metropolitan System, in Paris, places the bonds under the base flange of the rail. In England, solid copper pin type bonds, protected bonds inside of fish plates, and other types familiar in America, are generally used. (See Fig. 28, and Table 7.)

In Germany Thermit welds are used to some extent, and are becoming more common. In France the rails of the Cie de Omnibus Thomson-

TYPICAL RAIL BONDS - UNITED KINGDOM

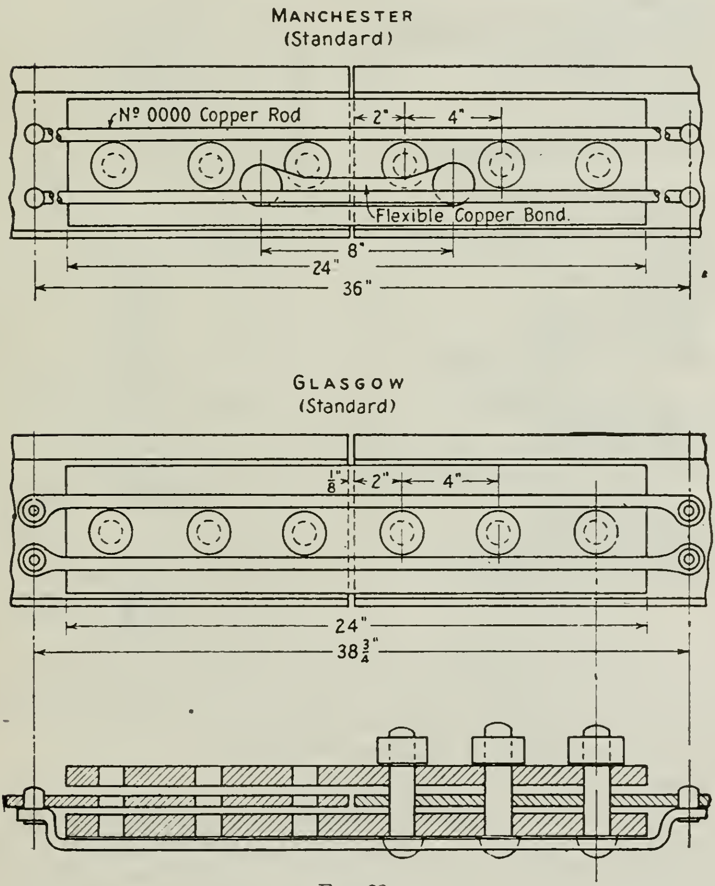


FIG. 28.

Houston are welded. In England Thermit welds have been used very extensively, giving good results electrically, but having short life due to mechanical weakness where traffic is heavy. A type of electrically welded

TABLE 7

RAIL BONDING, UNITED KINGDOM

	No. of Undertakings	Miles of Single track	Per cent of total (miles)
Copper Bonds.			
Solid copper, type not specified...	46	560.0	....
Flexible copper, type not specified.	9	176.0	....
Crown—3/0 and 4/0............	20	321.0	...
Neptune 4/0...................	19	229.2	....
Chicago......................	8	71.3	....
Forest City....................	5	37.2	....
Misc. and type not specified.....	15	406.8	....
Total, copper bonds only......	122	1801.5	47.3
Welded Rails, Etc.			
Continuous rails, type not specified........................	1	17 0	....
Yalk cast weld.................	1	20.0	....
Thermit......................	3	61.6	....
Thermit and Yalk..............	1	15.9	....
Thermit and Tudor.............	1	28.0	....
Thermit and Oxy-Acetylene......	1	18.0	....
Total, entirely welded.........	8	160.5	4.2
Partially Welded.			
Copper and Thermit............	31	1312.4	....
Copper and other welded joints..	5	377.3	....
Total, partially welded........	36	1689.7	44.3
Plastic Bonds, Etc.			
Plastic bonds and copper........	3	147.5	...
Plastic bonds and Thermit.......	1	12.3	......
	4	159.8	4.2

continuous rail, very extensively used in Leeds, and to an increasing extent in Manchester and Glasgow, is giving excellent results, being mechanically strong and providing good electrical conductivity.

4. Cross Bonds.

In Germany, cross bonds are used about every ten rails, i.e., every 100 meters (109 yards). In France they are placed every 50 to 100 meters (55 to 109 yards) and have the same area as the small rail-bonds. In England cross bonds are generally every forty yards (36.6 meters) and they have the same area as the rail-bonds. (See Fig. 29.)

5. Roadbed Construction.

The authorities consulted in Germany were of the opinion that the roadbed constructions used did not tend to effect a reduction of leakage from tracks; a similar opinion was held in England. The types of construction referred to were those illustrated in Figs. 30 and 31.

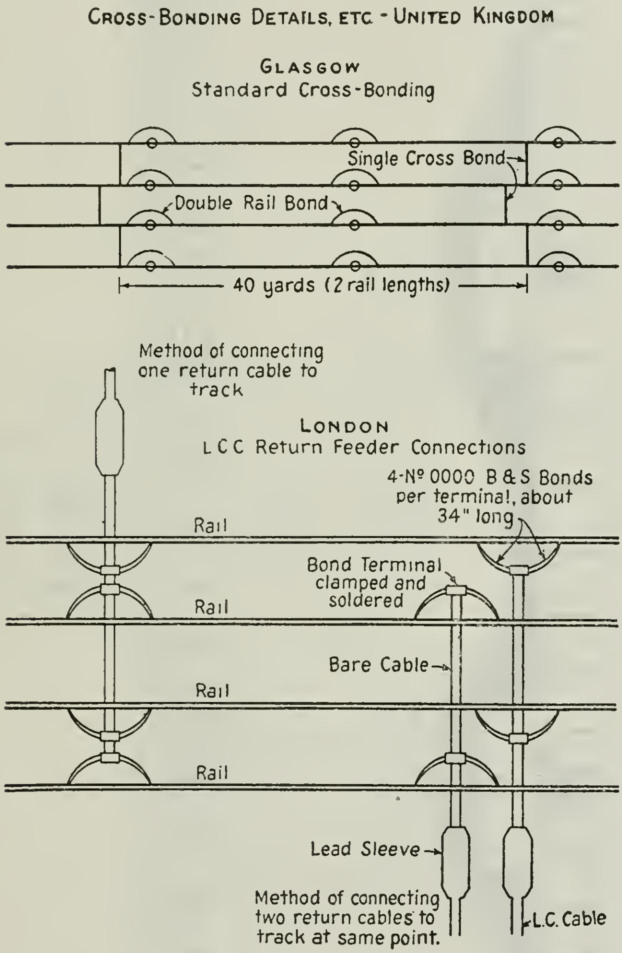


FIG. 29.

A later English report (1920) emphasizes the importance of thorough drainage as provided by broken stone foundations, as a means for reducing leakage current. The same report gives the following as good

Track Construction - United Kingdom

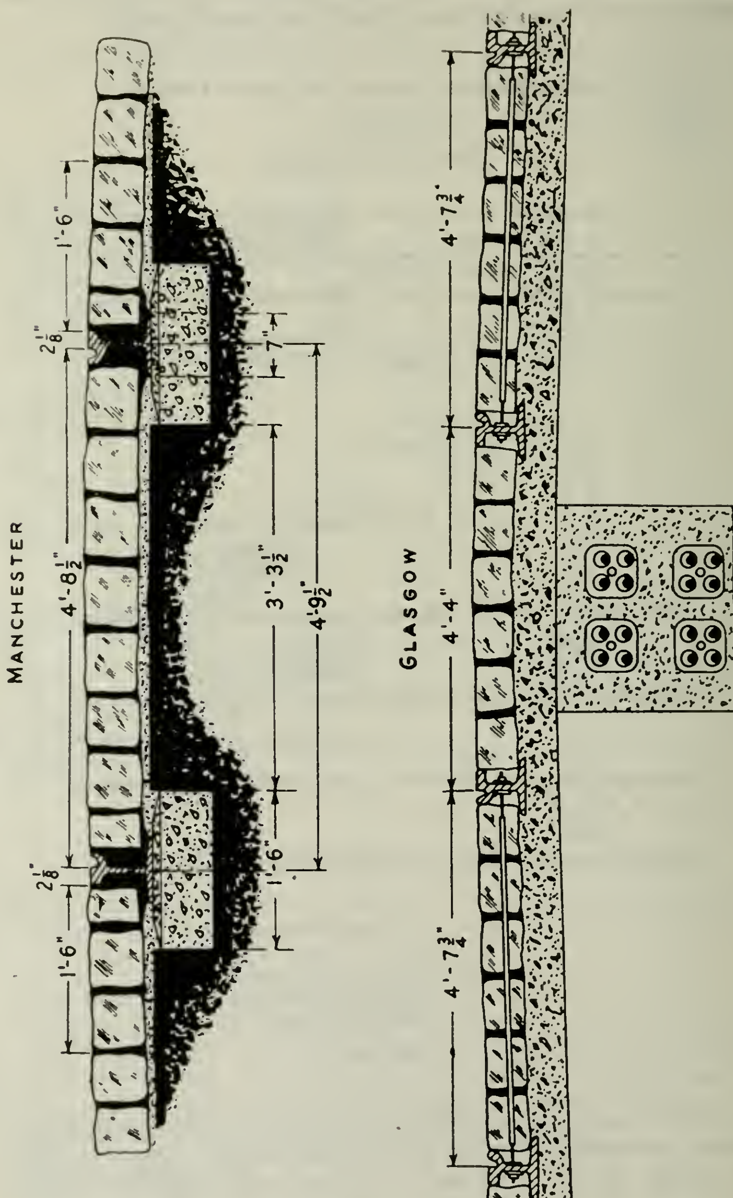
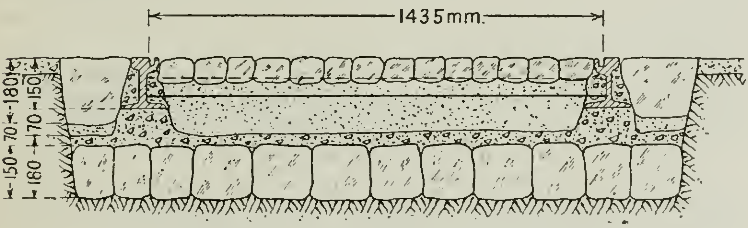


Fig. 30.

Length of Section		Per cent Leakage Current
Feet	Meters	
3,000	914	2.5
4,200	1,280	5.0
6,000	1,829	10.0
7,400	2,256	15.0
8,600	2,621	20.0
9,500	2,896	25.0

TRACK CONSTRUCTION AND RAILS - GERMANY



Typical Construction for paved street

STRASSBURG
Haarman 3 piece Rail, and foot plate

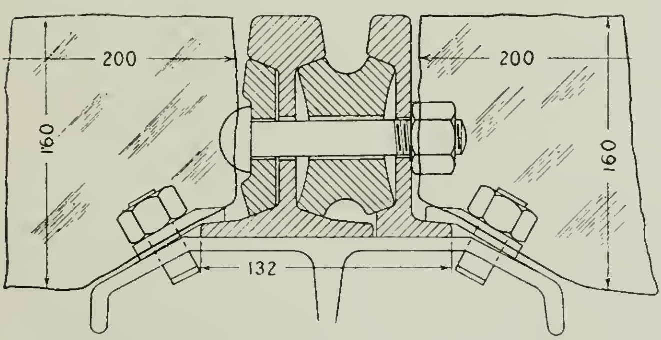


FIG. 31.

average leakage figures for tramway rails in direct contact with soil. The table is based on equal unit loading for various lengths of section.

Leakage current is proportional to the square of the length, and directly proportional to overall voltage.

The report also states that tests on railway tracks laid on wooden sleepers with broken stone ballast show about 25 per cent. of the leakage for tramway rails.

Tests made in Strassburg indicated that leakage currents were fifty per cent. greater in summer than in winter when the ground was frozen. In snow storms, however, the winter leakage currents were increased as the cars were using more current.

6. Feeders.

Insulated return feeders are used almost universally in Germany. In Berlin and Hamburg these return feeders are of the same number and size as the positive feeders, but generally in other towns the return feeders are of smaller cross-section. Separate feeders are generally used, but not exclusively, as feeders with resistance taps are used in some cases. Formerly there were cases of feeders tapping at several points but important cases have been corrected by the insertion of resistances. No design data for feeder resistances were obtained. The Hamburg installation of insulated feeders was made prior to the formation of the German Earth Current Commission. It gave valuable information in guiding the recommendations of the Commission.

Return feeders are not used for tramways in Italy; in large installation bare returns are generally used. In France most tramways have but one feeding point to the rails. Insulated return feeders are used for the conduit tramways in Paris, but little elsewhere.

In England insulated return feeders are used wherever they are necessary to bring the rail drop within the B. O. T. regulations; separate feeders are generally used. There is very little overhead feeder line construction in Germany, and almost none in England.

In Germany insulated negative feeder systems have been carefully calculated in recent installations. In England they are calculated only in the larger, well supervised systems; elsewhere they are installed by "cut-and-try" methods. The same grade of insulation is usually provided for both positive and negative feeders. The distinction between copper which merely parallels the rails, and feeders which are intended to reduce overall potentials by maintaining equipotential points in the rail network, is clearly understood in Germany and England.

Recent reports concerning heavy railway electrifications in England indicate that insulated return feeders are not generally used on such systems, possibly because they are not limited to the overall voltage of the Tramway regulations. The usual practice is to locate the sub-station close to the track and to connect the negative bus to the rails with short, heavy, cables. In general the negative busbars of sub-stations supplying electrified railways are not deliberately earthed, by means of earth plates, connections to piping systems, or otherwise. Two railway electrifications and some of the underground railways in the Metropolitan District provide an insulated fourth rail for return current, leaving the running rails free for signaling.

7. Negative Boosters.

Negative boosters are used in many places. In Germany the general practice is not to use them but they are much more extensively used in England (See Table 8) where they are generally found in the larger systems. They are considered more economical than resistances in the return feeders and also better for regulation where the load centers shift. In one large city their use was discontinued after they had been in operation for some time. The Tramways of Danzig, in Germany, operated by a private company and having a maximum load of 600 k.w., has used boosters since 1906.

Boosters are very little used in France; the only system found to be equipped with them was that of the Cie des Tramways de Paris et du Dept. de la Seine.

TABLE 8

USE OF NEGATIVE BOOSTERS, UNITED KINGDOM

	Number	Miles of single track
Total number of undertakings................	183	3,835.0
Number of undertakings using negative boosters.	39	1,152.0
Per cent using negative boosters..............	21.3%	30.0%

Relation Between Booster Capacity and Plant Capacity
Average, for 25 cases; Booster Capacity—3.9% of plant capacity.
Highest— 9 % for plant of 500 kw. capacity.
12 % for plant of 800 kw. capacity.
Lowest—0.8 % for plant of 5,725 kw. capacity.
0.9 % for plant of 3,500 kw. capacity.

The use of a negative booster in the return circuit of an electrified railway is mentioned in a recent report. The booster was installed for the purpose of relieving load on a section of the line, a cable being run out from the booster to the section to be relieved. The effects are reported as follows:

Section tested	Volts drop on Section		Per cent Decrease in Drop due to Booster
	Booster on	Booster off	
1st Section......	5.6	6.75	17.0
2d Section.......	5.75	6.9	16.7
3d Section.......	3.91	6.12	36.3

The booster was not continued in service because it was not effective in relieving the second section.

8. Double Trolley.

The double trolley system is not in general use in any of the countries visited. One or two very special cases near Laboratories in Germany, the district within two or three miles (three to five kilometers) of the Greenwich Observatory, and some conduit tramways of the London County Council System and in Paris were the only cases noted. The double trolley is also used in connection with a few miles of railless trolley in England.

9. Three-Wire System.

The three-wire system has been applied to electric railways in a few cases in Germany. In each case the distribution of load between polarities was by districts, that is, certain entire sections have the trolley wire negative. Under these conditions the systems may become considerably unbalanced.

In France, the Chem de Fer Nord-Sud, in Paris, employs a three-wire system with two motors per car, positive and negative, the running rails acting as a grounded neutral while the supply is provided by a third rail and one trolley wire.

The three-wire system has not been applied to tramways in England. The City and South London Underground Railway employed it, but this was to be discontinued following consolidation with other systems.

10. Negative Trolley.

The trolley wire was originally made negative in Nuremberg, and in St. Gall, Switzerland. The scheme has been abandoned in both places. This connection has not been used for tramways in Italy, France or England.

11. Pilot Wires.

In Germany permanent means for measuring overall potentials are very generally provided, but the methods of doing this vary widely. Pilot wires are usually provided for new installations in France.

In England pilot wires are universally used in connection with recording instruments. The practice varies widely, but the most common method employs No. 14 or No. 16 gauge wires laid with the main cables, and extended beyond them.

12. Bond Testing.

Bond testing is generally done in Germany on some systematic basis, more often annually, but in some large systems semi-annually. The bond-testing devices are generally of the three contact type with differential galvanometer. Some of these are said to be undesirable on account of the form of the contact, others because the rail points span too short a length, or on account of the type of galvanometer employed, etc. In

England it is stated that there is practically no systematic bond testing, except in the large well supervised systems.

13. Pipes and Pipe Joints.

Cast-iron pipes in England and Germany are generally of the bell and spigot type with lead calked joints. In Germany flanged joints are frequently used for special fittings, valves, tees and hydrant taps for water mains. Cast-iron pipes are little used in France; pipe joints are either lead calked bell and spigot, or in large pipes flanged, with rubber gaskets. Insulating joints are not used, except that in England it is said that they are occasionally used for water pipes in special cases.

14. Depth of Pipes Below Surface.

In Germany, gas pipes are generally laid 0.8 to 1 meter (2.6 to 3.3 ft.) and water pipes 1 to 1.5 meters (3.3 to 5 ft.) below the surface. In France, gas pipes are laid where possible 0.6 meter (2.0 ft.) below the surface, L. T. cables 0.7 meter (2.3 ft.) and H. T. cables 1.3 meters (4.3 ft.). In England 1 foot (0.3 meter) is said to be dangerous, 2 feet (0.6 meter) was given as an average by one authority, and 2.5 to 5 feet (0.8 to 1.5 meters) by another. In all cases the above depths are only typical, the practice varies widely.

15. Main on Both Sides of Streets.

In Germany, France and England mains are laid on both sides of the principal streets; in Paris, for streets wider than 14 meters (46 ft.); also in streets with wood or asphalt pavements, and generally in the larger towns. In narrow streets or unimportant places one main is used. In Paris the pipes for water are located in the sewers, not in direct contact with soil, and remote from trouble.

16. Insulating Coverings for Pipes.

In Germany it is held that insulating coverings do not afford protection against electrolysis, as their effect is merely to concentrate escaping stray currents since perfect coverings cannot be maintained. They should only be used where it is desired to protect against chemical corrosion from the soil. In France, gas engineers stated that insulating coverings were being studied, but it was not believed that they would prove practicable.

In England insulating coverings are not considered good protection against stray railway currents. High pressure gas pipes have been covered with pitch canvas, and the London Water Board pipes are provided with an asphalt dip coating, but more as a protection against chemical corrosion.

17. Electric Cables.

Cables are more frequently laid solid in the ground, and conduits are used less than in America. Metal conduits are only occasionally used in England; where they are used the cable sheaths are bonded to the conduits. Insulating joints are not used in Germany or England for telephone cables.

D. ELECTROLYSIS CONDITIONS

1. General.

Among the countries visited it was found that in Germany engineers and managers of the utilities concerned were fully alive to the problem of stray current electrolysis and they were well informed, due largely to the work of their Earth Current Commission. In England, although engineers and managers were generally informed, there was little lively interest in the question, due probably to the fact that there does not exist any acute electrolysis problem.

In France, the Government and the Paris municipality had recently (1914) appointed a Commission to investigate the subject of stray current electrolysis and make recommendations regarding the situation in the City of Paris. In Italy, troubles from electrolysis have been considered insignificant. Some of the larger systems in important cities are alive to the situation and are following with interest the developments in other countries.

Favorable reports of immunity from electrolysis troubles were based, as in Italy, on the absence of complaints. It was noteworthly that reports of damage were greatest where most thorough investigation had been made.

2. Voltage and Current Conditions; Experience with Electrolysis.

(a) *Germany.* Considerable damage was found in many cities prior to the application of the Earth Current Regulations; in one case service pipe trouble occurred as often as once a month. Generally, however, extensive damage was not known until it was revealed by investigation. Thus, many of the cities which were surveyed by the Commission, and where more or less corrosion was found, had previously reported no damage. In the past the majority of troubles have been on gas and water pipes, or at least these have received more attention in the reports. No cases of extensive damage to cable sheaths were found.

Many very thorough tests have been made in Germany and a large majority of these have shown that corrosion was being produced by stray railway currents. In general, the pipe owning interests stated that the situation was such that the work of the Earth Current Commission was urgently needed. Gas and water experts expressed the opinion that the regulations were too lenient, while the railway experts felt that they were too severe, maintaining that a considerable amount of corrosion ascribed to stray railway current was, in fact, due to other sources, or to self-corrosion.

In general, present conditions in Germany were considered satisfactory where the electric railways have conformed to the Commission Regulations; or where conditions were already equally good. In other cases the conditions were considered to be unsatisfactory. The more prosperous companies and municipalities spent money for improvements after the publication of the Regulations of the Earth Current Commission. Exact information was not available regarding the number of places where changes had been made, but the best information indicated that the number was between 20 and 30. Of these, Danzig, Strasburg and Erfurt expended about 100,000 marks each, rearranging the resistances of existing return conductors, and Dresden was engaged in 1914 in insulating the existing bare return conductors. Generally, the most important cities were rapidly improving their return circuit conditions. Also, other undertakings not subject to the Regulations were changing over voluntarily for reasons of policy or economy, or as the result of compromise to avoid litigation; this was said to be the case in 30 or 40 important towns. A litigated case, in Mansfeld, was decided against the gas company on legal grounds as the railway existed before the gas plant.

Where return circuits have not been remodeled in accordance with the Commission Regulations, overall voltage limits vary greatly, but in the majority of cases they are between 5 and 10 volts overall. Measurements were made by the Sub-Committee of one large installation having negative feeders equal in number and area to the positive feeders; it was found that the maximum drops in rails were well within the limits prescribed by the Regulations.

(b) *Italy.* From a survey made about 1908 in a city of Italy, it was found that the maximum difference of potential in the rails between the station and points about three miles (5 kilometers) distant were as great as 17.5 volts. In this installation they had not received complaints of serious damage by electrolysis, except a few gas service pipes, although the railroad itself had experienced some difficulties on water pipes at one of its yards.

(c) *France.* The Sub-Committee's investigation was somewhat limited in France. No adequate or complete tests have been made, although some testing has been done in Paris following the development of trouble. It is stated that tramways in France generally endeavor to observe the 1 volt per km. limit (1.6 volts per mile), and that potential differences between pipes and rails rarely exceed one volt.

In general serious electrolysis troubles were found only in a few places, either created by heavy traffic lines or by peculiar conditions not readily explainable. Outside of Paris there is little damage caused by tramway systems. In the suburbs of Paris all underground pipe systems are more or less affected. In Paris 60 to 70 cases of damage to pipes have been found in a year—the actual cost of repairs was estimated to be 60,000 francs, but it was held that the paramount consideration was the danger to security of service, since nearly all cases caused property losses in buildings, although there were no explosions.

At least a third of the total number of cases reported were due to the rearrangement of the old two-wire, three-wire and five-wire systems of electric light distribution, but these troubles were of a temporary character and were promptly remedied as soon as discovered. In the other cases, due to stray railway currents, the troubles were persistent. About twenty litigated cases for electrolysis damage were pending in Paris in 1914.

A very considerable amount of damage in Paris is due to the "Metropolitan" subway system which claims exemption from the 1 volt per km. (1.6 volts per mile) regulation, not being a tramway. At one place in Paris a potential difference of 6 volts between a railway structure and a pipe was observed by the Sub-Committee.

There are few telephone cable troubles in Paris due to electrolysis.

(d) *Great Britain.* Considerable damage is said to have occurred in the early days of electric traction in England, although such damage was apparently insignificant compared to conditions familiar in America during the same period. Practically no damage has occurred in recent years, and certainly no extensive damage. Two or three cases, local in character and of small extent, have occurred in localities where the Board of Trade Regulations were complied with.

In England there is very little good evidence in the way of tests, and the general statements of immunity are based on absence of trouble. The Post Office, and the South Metropolitan Gas Company of London, both make systematic tests and find no trouble except that the Post Office has, from time to time, encountered difficulties quite local in character, due to stray currents.

The Board of Trade Regulations are not considered onerous by any of the railway engineers consulted. All authorities representing the pipe owning companies, the tramways, the state telegraph and telephone, and the Board of Trade, were unanimous in stating that the electrolysis situation for the properties under their respective control was entirely satisfactory. Nevertheless, there is considerable feeling among the privately owned gas companies that they are not adequately protected, since, as noted elsewhere, they cannot recover damages in case corrosion occurs where Regulations are complied with.

Overall rail drops for tramways in England are generally very much lower than the Board of Trade requirement, averaging probably 2.5 to 3 volts, with the exception of occasional drops, which may be as high as 15 or 20 volts, due to extraordinary traffic at football matches, etc. The average overall drops for several large cities visited by the Sub-Committee during June and July, 1914, were about 2 volts. Glasgow, which voluntarily adopted a 2-volt rail drop, Manchester, and other large towns, have extraordinarily low rail drops.

The electrification of branch railway lines has been carried out to a considerable extent since 1914, and some data were obtained in 1920 concerning the voltage drop in the return circuits of such lines. Two electrified sections of an extensive railway system are reported to have maximum instantaneous voltage drops as follows:

A.. 43 volts
B.. 77 volts

Another railway reports in general that the voltage drop for its electrified sections is higher than that permitted for tramways; and in particular that the worst section gives a maximum drop of 25 volts for 15 to 20 seconds, with instantaneous maxima considerably higher.

Potential differences between pipes and tramway rails are said to be generally less than 1 volt.

E. MISCELLANEOUS OBSERVATIONS

1. Drainage System.

Electrical drainage as a palliative measure for electrolysis was formerly applied in one or two cases in Germany, notably in Aachen, but it was abandoned on account of damage produced by it, first due to joint corrosion, and second, damage to other underground structures. It is condemned by the engineers of the Earth Current Commission.

In England, drainage is not approved as a general measure to afford relief from stray current, although there are a few special instances of its application to the tramway company's own lead-covered cables, where the common practice is to bond to the rails at many points.

2. Corrosive Effects of Soil; Earth Resistance.

In Germany the possibility of chemical corrosion (that is, corrosion without an external supply of electricity) is recognized, and distinction is made between such corrosion and that produced by stray currents. Pipe corrosion has actually been found under conditions where it could not have been produced by stray currents. No definite information was obtained in England regarding the corrosive properties of soil, but it was stated that chemical corrosion was known to occur. Such corrosion does not, however, produce acute conditions as in electrolysis; it is more like ordinary oxidation.

German reports gave the resistance of soil as varying from 1 ohm to 2,000 ohms per cubic meter (1.3 ohms to 2,616 ohms per cubic yard), averaging about 100 ohms per cubic meter (131 ohms per cubic yard). In England no specific information was obtained concerning earth resistance. One report states that the provisions of clause 5A of Tramway Regulations (for two earth plates not less than 20 yards (18 meters) apart between which an E.M.F. not more than 4 volts shall produce current of 2 amperes) cannot be met even at permanent water level, and that in general the apparent resistance is about twice that required by Regulations.

3. Electrolysis Testing Methods.

In England very little testing is done to investigate electrolysis questions and no technique has been developed for such work. The only extensive work in recent years is that of the Cunliffe brothers, and their work was directed mainly toward the investigation of certain theoretical questions rather than toward the systematic investigation of actual experience with stray currents.

In Germany the work of the Earth Current Commission has been already noted. The surveys made by the engineers of the Commission are systematically planned; they are made in the most excellent technical manner. The reports are quite uniform in character; they start with a general investigation of geological conditions, the character of the soil, ground water, etc., continuing with a general survey of the present condition of the railway property, including distribution of load, track and rail resistance, location and loading of supply and return circuit cables and any other electrical data relating to the investigation. The surveys then take up the specific measurements relating to stray current, such as potential differences between pipes and rails, current in pipes, and so forth. Reasoning from the data presented, recommendations are made for improving conditions, where improvements are needed, sometimes with estimates for the cost of the work. In some cases a supplementary report is made which shows the conditions after the changes have been made. The conclusions arrived at appeared to be practicable and reasonably acceptable to all parties concerned.

4. Economic Aspects of the Electrolysis Problem.

About forty per cent. of the electric railway systems in Germany, and about seventy per cent. in Great Britain, are municipally owned. In Germany one authority thought that municipalities were more ready than private companies to spend money for the purpose of improving their return circuits, but in England it was thought that there was no difference in this respect. It was said in Germany that where municipalities owned the water, gas, and tramway systems, they may prefer to assume the cost of damage rather than make large expenditures for protecting their pipes.

Also in Germany, a study of the survey reports of the Earth Current Commission indicated that in no case was the yearly cost of repairs for damage by electrolysis of such amount that, on the surface, large expenditures for improvements would be justified. The Commission, however, while recognizing the importance of the financial aspect of the problem, still recommended the adoption of the relatively expensive remedies for the reason they state—"that the repairs will certainly become more frequent with lapse of time, and besides the increased expense so caused, there is the liability of service interruption, disturbance of traffic, pavement replacement and even danger of explosion to be considered."

Opinions differed in Germany as to whether or not the prevailing regulations constituted a financial hardship. In England, the Board of Trade Regulations are nowhere considered a hardship, and where inquiry was made as to whether the existing regulations had retarded the development of electric railways, the authorities consulted uniformly stated that this was not the case. It appears that in fact a saturation point has been reached, and busses are being used where tramways would not pay. Traffic conditions are said to be quite as heavy in England as in the United States. Only one authority in England ventured an estimate of the average load factor for English electric railways systems; he estimated it to be thirty-five per cent.

5. Application to American Conditions.

Disputes on account of electrolysis troubles have been prevalent in the past in all countries having any considerable electric railway development, before systematic co-operative studies or regulations were applied; this in spite of the fact that the mode of life and distribution of population and industries are more favorable than in American cities. The average weight of cars in foreign cities is less than in America, and the tramway traffic and power requirements may be one-fifth or less in Europe than in America for cities of the same population.

A city like Berlin with over 2,000,000 inhabitants handled all of its transportation with a maximum load of about 30,000 k.w. (Chicago with over 2,200,000 population required a maximum load of about 200,000 k.w.) Manchester with a population of 1,250,000 and Glasgow with 1,000,000 had traction loads of 11,000 k.w. and 11,500 k.w. respectively. (Boston and the territory served by its traction system with about 1,150,000 people, required station capacity of 75,000 k.w.) Milan with a population of over 600,000 had a traction load of approximately 8,00 k.w., and Nurnberg with 350,000 inhabitants used only 1,000 k.w. (The city of Worcester, Mass., with a population of approximately 160,000 required power station capacity of 7,500 k.w.) These comparisons should be taken into consideration in applying to this country the results of this investigation of foreign practice.

These comparisons, however, should not be taken as a definite index to comparative electrolysis conditions, since many other factors are involved. Regardless of the degree of improvement which economical limitations may make permissible to accomplish in local situations, the fundamentals for the solution of the electrolysis problem evolved abroad merit the most careful study to ascertain their possible application to American conditions.

F. SUMMARY

In Europe, the effectiveness of the co-operative or regulatory measures applied to the electrolysis problem may be summarized as follows:

Germany, through voluntary co-operation, has probably remedied the former dangerous electrolysis conditions for all of its important systems. The instrumentality of agreements on definite technical standards was sought in preference to legislation.

France has not been as successful in bringing prompt results through legislation as has Germany through technical co-operation.

England which has had government regulation for many years has now no electrolysis troubles or disputes.

Italy will probably give more consideration to the subject of electrolysis whenever the general conditions will permit.

The methods followed to attain the satisfactory results obtained abroad are these:

1. Maintenance of good bonding.
2. Elimination of intential contacts, and liberal separation wherever possible, of pipes and rails.
3. Avoidance of bare copper returns and use of insulated returns in all installations where the conductivity of the rail alone would give a too great maximum drop.

4. Use of insulated return feeders with balancing resistances, or to a lesser extent "boosters" for the purpose of maintaining equality of rail potential at the feeding points of all feeders.

Small feeder drops and frequent sub-stations to give close line regulation.

G. EUROPEAN REGULATIONS ADOPTED AND PROPOSED

Germany—Earth Current Commission's Recommendations

Recommendations of the German Earth Current Commission as Adopted by the Gas, Water, and Railway Interests of Germany

Regulations for the protection of gas and water mains from the electrolytic action of currents from direct current electric railways which use the rails as a return.

Accepted for two years at the yearly meeting of 1910 and for a further two years at the yearly meeting of 1912.

Published in the Electrotechnische Zeitschrift, 1910, page 491, and 1911, page 511.

Section 1. Application of Rules

The following rules govern the installation of direct current railways or sections of direct current railways which use the rails for carrying the return current. Unless otherwise mentioned the herein given admissible potential values should be adhered to when laying out new railways. For determining the resistance of a line, the rails only must be taken into account as current carrying mediums and the assumed resistance of the rails, as well as the assumed percentage increase of resistance due to the bonding must be stated.

These values must not be exceeded, either when making the necessary calculations or by the plant when in actual normal operation.

These rules do not apply when railways are laid with special track or when the rails are laid on wooden sleepers, in which case there is generally an air clearance between the rails and the stone ballast; but the rules do apply if this air clearance does not exist, as at grade crossings, unless an equivalent insulation is provided for locally. Further, these rules do not apply to railway lines which do not approach closer than 200 meters to an underground pipe network.

Explanations.*

The regulations apply only to direct current railroads or sections of such, using the rails as conductors. Railroads not using the rails as conductors are eliminated from the start, because the same do not send any currents into the earth and therefore cannot have any damaging influence on the pipes. According to the experience reached so far, alternating current seems to have very little effect, so that any extension of these rules to cover also alternating current railways does not seem

*Note.—This explanation and the other following are included in the German Earth Current Commission's recommendations.

justified. At any rate, the conditions produced by alternating current railways are not yet sufficiently understood to allow of establishing any restrictions in regard to their equipment and operation for the protection of pipes.

In case a railroad is operated partly with direct current and partly with alternating current, these regulations apply only to those sections, the rails of which carry direct current. The fixed upper limits of permissible potentials apply to the design of the plant, unless otherwise stated, and in the calculations only the rails and the bonds are to be considered as far as the conductivity and the resistances of the conductors are concerned. The assumed resistance of the rails and the increase of same by the resistance of the bonds is to be stated, and such limiting values are not to be exceeded either by calculations or in practice.

The earth as a shunt is not considered. Through contact of the rail network with the ground, a part of the current passes into the ground and the potentials of the rail network are thereby lowered as compared with a case of perfect insulation from the ground, the effect becoming greater, the more the current passes into the ground. It is, therefore, not correct to take the differences of potentials as found immediately after the construction of a rail network as a basis for estimating the safety against damaging influences, but it is necessary to go back to the first cause, that is to say, the differences of potential as they would be if the rails were completely insulated.

This rule allows of an exact calculation of the conditions during the design of the plant without any uncertain and varying values for different localities. The limit values are not to be exceeded either during the calculations or at the actual practical test. The method of the practical test will be discussed in Section 3. The projection of the plant is, therefore, to be based on assumptions as correct as possible with regard to the resistance of the rail, the cables, and the consumption of current, and it is advisable to consider also a later increase of the traffic.

Railroads, the rails of which are insulated on special roadbeds, generally have such a great resistance against the earth that passage of current into the ground of such magnitude as to be considered dangerous to pipes does not occur. Higher potentials, therefore, are permissible for such railroads, assuming that a sufficient insulation is provided for also on grade crossing, etc.

As a means to this end are to be considered:

Insulating strata between rails and ground, for instance, tar paper, which must extend on all sides sufficiently beyond the place in question; or the surrounding of the pipes with insulating material. Such places are to be inspected from time to time to ascertain the effect of such insulation.

For the exemption from these regulations the laying of the rails on a special roadbed is required, because it is only in this way that a permanent insulation can be reached and maintained. About the details of the system of insulation to be used, no rules were issued. A lasting insulation is to be guaranteed by the way in which the rails are laid. The laying of rails on wooden ties as mentioned above is intended as an example only. At any rate to secure satisfactory insulation it is imperative that the rails be nowhere in contact with the moisture of the ground, as this greatly favors the passage of the current into the ground.

Tracks which are at all points at least 200 m. distant from any pipes are exempt, because any current coming over such an extended area spreads to such a degree that its density cannot possibly be harmful. In this resptct concession has been made to long outlying railway lines because the subjection of such to these regulations would entail great economic disadvantages in certain cases. The maintenance of good conductivity on such outlying sections is to be strongly recommended so as to prevent the return currents from reaching a dangerous density where such sections join the rails of an inner rail network, i. e., a density exceeding the limit given in Section 5.

SECTION 2. RAIL CONDUCTORS

All rails serving as return conductors should be built with regard to this requirement, should be made as good conductors as possible, and should always be kept in good order.

The percentage of increase of the resistance of a given length of track due to the bonding should not exceed the value assumed when laying out the railway, and must not be more than 20 per cent. more than the resistance of the same length of track if the rails were without joints and of the same cross-section and the same specific conductivity. On laying out a railway line consisting of main and auxiliary rails, the combined cross-section of both rails can only be taken into account when determining the resistance of the track, provided the auxiliary as well as the main rails are properly bonded and cross bonded.

At rail crossings and at switches, the rails must be well bonded by special bridge bonds.

On single tracks as well as on lines where several tracks are lying side by side the rails must be efficiently cross bonded and these cross- and bridge-bonds must have a conductivity at least equal to a copper conductor of 80 square millimeters.

At all movable bridges or similar structures which necessitate an interruption of the rails, special insulated conductors have to be provided which secure a continuous connection between the two rail ends. In such cases, the voltage drop at average load must not exceed 5 millivolts for each meter distance between the interrupted rails.

All current carrying conductors which are connected to the rails must be insulated from earth, excepting short connections such as bonds, cross-bonds and bridge-bonds at switches and turntables. If such bonds are laid not deeper than 25 centimeters into the earth, they may be bare conductors.

Explanation.

The first condition for the reduction of stray currents and for the effectiveness of all the proposed precautionary measures, is the good conductivity of the tracks and the maintenance of this conductivity. High resistances of the single sections cause an increase of the current passing into the ground. The maintenance of the good conductivity of the rails also is to the economic interest of the railroad, because a bad conductivity will, under certain circumstances, cause loss of energy.

It is not desirable to issue rules concerning the cross-sections of rails or for the conductivity of the steel because the cross-section and the chemical composition of the steel are both determined by mechanical considerations; the conductivity is dependent on the composition of the steel, while the conductance of the rail depends on both the conductivity and the profile.

The resistance of a rail network is widely influenced by the quality of the electrical connections of the rails at their joints.

The rules do not recommend one or another system of connections at the joints, but give data covering the permissible increase of the resistance by such connections.

In consideration of the varying resistance of rails of different profile, it is not possible to establish a uniform permissible resistance for a bond but the permissible increase of the total resistance of a section by all the bonds is given. This increase must not be over 20 per cent. Inside of these limits the designing engineer may assume any increase of the resistance by the bond, but it must be considered that the increase assumed must be permanently maintained later on (compare Sections 6 and 3).

It will be well to assume during the design of the plant, the increase of resistance of the bonds as very near the permissible limit. This is very important when shorter rails are to be used, with the consequent greater number of joints, the maintenance of which is correspondingly more difficult and, therefore, an increase of resistance through deficient bonds to be expected. The conductivity of rails is to be ascertained on a number of samples before the rails are laid, so as to have a guarantee that the calculated resistance will correspond to the resistance of the finished work.

The measurement of the resistance is made by measuring the current and the potential on a rail as long as possible and insulated from its supports; the potential terminals should include a part of the circuit between the current contacts and they should be at least 0.5 meter distant from these current contacts. A simple calculation gives the conductivity of the rail by using the value shown by ammeter and voltmeter. The conductivity of the rails now in use is generally found to be between 4 and 5.5 Siemens (10.5 to 14.4 times the resistivity of copper).

In cases where main and auxiliary rails are to be used and where the combined cross-section of both is taken into calculation, the conductivity of the auxiliary rail also is to be measured as the same may differ considerably from the conductivity of the main rail.

At crossings and switches a loosening of the rail connections will take place caused by the vibrations brought about by the passage of the rolling stock, for which reason such places are to be bridged specially by electrical conductors. The cross connections serve the purpose of eliminating differences of potentials between tracks running side by side and also to insure a good metallic connection between the rails on one side of a track in the case of a temporary low conductivity of single joints or interruptions.

It seems advisable in consideration of the different length of rails, not to give an absolute distance between the cross-connections, but to establish their number by the number of joints. The bonds and cross-connections may be of any material as long as their conductivity reaches at least that of a copper connector of 80 square mm. For the connection of interrupted tracks, as for instance at movable bridges, insulated cables are required because of the presence of water or other substances in the soil, which highly favor the passage of currents into the ground. The highest permissible drop in potential at average load has been fixed at 5 millivolts per meter distance between the places of interruption, to insure a small difference of potential between these points.

Furthermore care is to be taken that the tracks in a movable bridge are in good contact with the tracks on both sides of it. The following is an example of the calculation of a cable bridging across the gap.

When the distance between the tracks at the point of interruption equals 30 meters, the permissible difference of potential, therefore, is 5×30, which equals 150 millivolts. The current to be carried across is assumed to be 120 amperes and the length of cable 30 meters. Assuming a specific resistance of 17.5 milliohms per meter and square millimeter, the resulting cross-section is:

$$q = \frac{17.5 + LI}{e} = \frac{17.5 \times 30 \times 120}{150} = 420 \text{ sq. mm.}$$

Inasmuch as the increase of the surface contact between the conductors and ground results in an increase of the current passing from the conductors into the ground, the conductors connected to the rails, especially those lying deep enough to come into contact with the moisture of the ground, are to be insulated conductors. Only short connections, such as jumpers on crossings and switches, are exempt from this rule on account of the same not lying deeper than 25 cm. under the surface, which means that they hardly come into contact with the moisture of the ground. The increase of surface of the contacts with the ground by these conductors is too small in proportion to the total surface of the rail network to cause any apprehension regarding the currents passing into the ground.

Section 3. Rail Potential

A railway network is divided into two sections, first, the open road connecting the various townships, and second, the urban network.

In the urban network and for a distance of 2 km. beyond, the voltage drop between any two rail points should never exceed 2.5 volts when the line is working under normal conditions, and the drop in the rails for each kilometer of open road should not exceed 1 volt. Occasional night cars are not to be considered in determining the average load.

In townships through which only a single line is run, without local rail network, the total voltage drop in the rails must not exceed 2.5 volts from end to end of the township's pipe network.

Any apparatus which is supplied with current and which is connected to the railway network must not increase the voltage drop above the stated limits.

If various railway systems are connected together either through the medium of the rails or through the power station, each system must fulfill the above conditions. A rail system in a township with an independent pipe network has to comply with the above regulations also.

Exceptions from these rules in regard to the voltage drop in a railway network are admissible if local conditions and service necessitate and justify such exceptions. If, for instance, the service—as is the case in freight yards—covers only a small portion of the day, the above limits of rail drops may be exceeded. In yards with a service up to three hours daily, double the above values are permitted, and with a service up to one hour, four times the above values are allowed.

Explanation.

As mentioned in Section 1, the rail network is to be considered as insulated from the ground, so that the earth as a shunt is not considered.

The resistances of the single sections are to be calculated from the resistance of the rails under observance of the rules in Sections 1 and 2.

For the calculation of the potentials the value of the average current is to be used, as the magnitude of electrolytic decomposition of the pipe metal depends on the quantity of current, that is to say, the product of current and time. The highest values have not to be considered for the calculations. To find the consumption of current the average service as per schedule has to serve as the base.

The average current consumed on single sections can be calculated from the number of car km. or ton km. to be covered, by using the value for the consumption of current which, according to experience, and in consideration of the local conditions, is used for one car km. or ton km.

But is is also permissible to distribute the consumption of current over the whole net in a way corresponding to the locations of the single trains at the time of the average load and to calculate for each train the consumption of current taking into consideration the weight of the cars, the speed and operating conditions (grade, stops).

In regard to the schedule, the difference between summer and winter service is to be considered. The increase at regular intervals, as for instance on Sundays, is to be taken into account. Small deviations from the schedule, as for instance, single night cars, or auxiliary cars, shall not be considered, because the first would reduce the average value out of proportion, and the frequency of the second cannot be estimated at the time of the calculations and otherwise are not of any appreciable influence on the final results.

It is impossible to get regulations embracing all conditions and possibilities and it is therefore necessary to consider all peculiarities of a plant during its projection. If there are any additional places connected to the rails, where current is used for stationary motors, station lighting, etc., these are to be considered.

After the drops in potential on the central sections have been tabulated, based on the above calculations, the distribution of the potential in the rail network can be found. In addition to the foregoing data for the calculation of the drop in potential on the single sections, consideration is to be given to the proposed return cables and, in case of a three-wire system, to the direction of the current in the districts of different polarity.

Difference in potential between any two points of the rail network must answer the following conditions:

Around every individual pipe network (meaning a network not in metallic contact with any other network) and also around single pipes, a zone of 200 m. is to be circumscribed and all tracks lying outside of this zone are not to be considered in connection with these regulations, as per last part of Section 1.

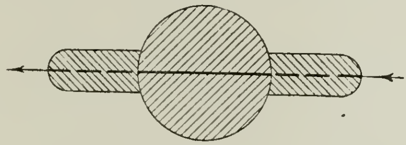
For each of the rail branches lying inside of these individual pipe networks, the following rules apply:

If there are any branches of the railroad inside of a pipe network, including the 200 m. zones, a belt 2 km. wide is to be laid around the inner rail network. Inside this belt the potential of the rails between any different points must nowhere exceed 2.5 v., as long as no portion or the rails is more than 200 m. distant from the nearest pipe along its total length. (Compare Fig. 32.)

On the sections outside the 2.5 v. districts, the drop in potential must not exceed 1 v. per km. This applies to outlying sections which are shown in Fig. 32 by heavy dotted lines.

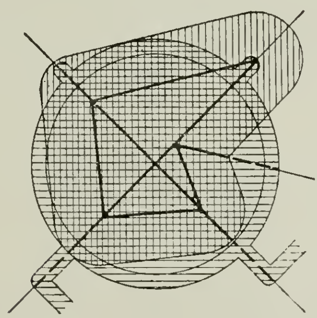
In the case of a railroad with no branches (country roads) and a pipe network, the drop in potential inside the pipe network must not exceed 2.5 v. (Compare Fig. 33.) The rule establishing a drop of 1 v. per km. states that the current in the track must not exceed $\frac{1}{W}$ if W is the resistance of the track in ohms per km. For a uniform load of a section of L km. length and a uniform resistance, the permissible drop in potential is $\frac{L}{2}$ v. i. e. one-half the drop in one rail. The calculation of this drop is also based on the average load, according to the schedule.

Strict rules have been issued for the interior rail network with its many branches, as it mostly covers the same area as the pipe network. This has been done in consideration of the greater surface of contact between ground and rails and pipes, respectively, which increases the probability of a passage of current through the ground. The potential 2.5 volts for this district has been judged permissible because, according to the results of previous investigations, it is to be assumed that this potential will not under ordinary conditions cause any danger to pipe lines beyond practical limits. To avoid as much as possible any greater concentrations of ground and pipe currents at the outlying sections which immediately join the inner rail network, and where important parts of



District of interior pipe - network.
District of 200 m. around pipes with no branches.
Railroads in the 2.5 V. District.
Railroads in the 1 V-Km District.
Railroads with no Restrictions.

FIG. 32.



District of the pipe-network with the 200 m. belt surrounding it and the pipes with no branches.
District of the interior Rail-network with the 2 Km. belt surrounding it
Railroads in the 2.5 V. District (shaded by both horizontal and vertical lines)
Railroads in the 1 V-Km District (shaded by horizontal lines)
Railroads with no restrictions (not shaded, or by vertical lines only)

KEY TO CALCULATION OF VOLTAGE DROP IN RAILS.

FIG. 33.

the pipe often extend, strict rules have been issued covering the district inside the 2 km. belt around the inner rail network.

For the outlying section an economical advantage has been contemplated by limiting the drop in potential to 1 v. per km. Railroads interconnected by their rail networks or by a common power plant are to be considered as one system because such railroads influence each other, inasmuch as equalizing currents will flow between their rail networks.

Deviations in both directions from these potentials can be justified by certain circumstances—in case of especially good conditions of the ground, that is to say, in very dry dirt an increase of the potentials may be permissible. But even in such cases it is advisable to be cautious in allowing such an increase, so as not to violate the rules as given in paragraph 5. Where the conditions are unfavorable, for instance, where moist ground of especially high conductivity prevails, it is advisable to remain below the limits. For railroads with brief daily operation concessions have been made because damage to the pipes depends upon the duration of the influence of the current so that, considering the short time of operation, even greater currents cannot cause any appreciable damage to the pipes.

For railroads of three hours daily operation double drop in potential is allowed, while for railroads of one hour operation, four times the drop is permissible. Wherever the rail network is not sufficient to carry the current without exceeding the permissible potential in the network, the whole plan for the return of the current must be altered, and improvement will be reached by providing return cables in which, if necessary, resistances or boosters may be inserted. The resistances should be variable so as to correspond with the variable conditions of service and operation. In cases where the railroad system is fed from several power plants a reduction of the drop in potential in the rails may be brought about by shifting the loads of the several power plants.

The arrangement of the cables and resistances can be made in so many different ways as to make a general rule for all cases impossible. It is recommended to investigate thoroughly the cases under observation, because considerable saving in the construction and operation of the plant may be achieved by a careful layout.

The keeping of the return points at the same potential is recommended as a precautionary measure but not required. The same offers a certain guarantee of the possibility of keeping the difference of potential within the 2.5 v. limits.

Furthermore, the use of the three-wire system with the rails as a neutral conductor is worthy of consideration. In this system the difference of potential in the rails depends on the distribution of the positive and negative feeder districts. This distribution again depends on the local conditions of the plant, so that no general rules can be given in regard to it.

Alterations of the conditions of operation can be counteracted by switching the load to the positive or negative side of the system. The rules do not recommend any certain system, but leave it entirely to the projecting engineer to select the one best adapted to existing conditions. The damage to pipes takes place mostly at points of low potential on two-wire railroads, in the neighborhood of the return points; and on three-wire railroads, in the districts of negative feeders; because it is mainly here that the current leaves the pipes. It is advisable to place the return points of the negative feeder districts whenever possible in locations with dry ground of low conductivity and as far as possible from such pipe lines as are of importance for the water and gas supply.

The permissible limits of differences in potential in rails must not exceed, either according to calculations or at the practical trial, the limits given in Section 1, of these rules. The measurement of the difference in potential is made by means of test wires as called for in Section 6. The measurements of differences in potential are limited to those points which, according to calculations, come nearest to the established limits. Wherever long lines, as, for instance, telephone wires, are available, it is advisable to use them for these measurements, otherwise several test wires may be connected in series or temporary test lines may be installed. Finally, the results of single measurements may be computed to reach the same final results. Only high resistance voltmeters should be used for these measurements so as to make the resistances of the test wire and contacts negligible. The pointers of these instruments should have the slowest movements and a good damper arrangement, so as to give good readings even under strong fluctuations. For all measurements only average values are considered. All measurements are to be extended over a full period of operation which results from the average frequency of trains.

Section 4. Resistance Between Rail and Earth

The resistance between ground and the rail which is used for carrying the return current should be kept as high as possible. When the conditions of the ground or the situation of the track are not favorable for this purpose, the resistance should be increased by a special effective insulation.

The rails or any conductor connected to the rails must not be in contact with the pipes or any kind of metal buried in the ground. Furthermore, care must be taken that the distance between the nearest rail and any metallic part of the pipe lines or connections to them which project above the ground or lie near the surface, be kept as great as possible, and should never be less than one meter.

Stationary motors, lighting installations or any other plant which receives current from a railway system which uses the rails for carrying the return current must be connected to the rail network by means of insulated conductors. Excepted are short connections of not more than 16 square millimeters which are not deeper than 25 centimeters in the ground and which are at a distance of at least 1 meter from any part of a pipe network. These connections may be of bare metal. In order to increase the resistance between rail and ground it is recommended to use a bedding of high resistance and to provide good drainage, also to render the bedding water-tight to the roadbed for a sufficient width on both sides of the rail.

The use of salt for the melting of snow and ice should be limited to cases of absolute necessity.

Wherever sufficient distance between the rail and such parts of the pipe line as project above the surface is not obtainable, it is advisable to change the pipe run, or where this is not possible, to use insulating strata such as vitrified clay, masonry or wooden conduits, etc.

Explanation.

The magnitude of currents passing into the ground depends not only on the potentials in the rail network, but also on the resistances between the rails and the pipes and on the resistances of the pipe lines themselves. It will always be of advantage to increase the resistance of the ground between the rails and the pipes. An artificial increase of the resistances of the pipe line can be achieved, for instance, by the use of insulating flanges, couplings, etc. Aside from the technical difficulties of installing such insulating parts into gas pipes, and especially water pipes with a high pressure, and of insuring their lasting tightness, it would be difficult to provide these insulating pieces in the necessary numbers and to take care of their correct distribution. A wrong arrangement of the same will lead to an extraordinary concentration of currents at these insulations with consequent corrosion in these places. A greater part of the drop in potential between pipe and rail originally takes place in the roadbed, as can be easily understood, and it is therefore required to render this resistance as high as possible by the good insulation of the roadbed, good drainage, etc., and to maintain it thus.

In the same measure that the increase of the resistances between rail and pipe is recommended, the use of any means to reduce these resistances is to be warned against. Such means to be considered are ground plates, connections of metals in the ground, and especially metallic connections between the rails and the pipes. The last will reduce the density of the current at the point of connection to the pipe, but they cause an increase of the pipe current and of the ground currents in general which may cause damage in other places, as, for instance, at interruptions in the pipe lines or at crossings with other lines. Any local measure taken must be considered with regard to its effect on the pipes in other localities.

Metallic connections between different pipe networks also are to be judged from this viewpoint. Immediate contact of any parts of the pipe lines with the rails, or too close an approach, has the same effect as direct metallic connections and is, therefore, to be avoided (by a relocation of rails or pipes or installation of insulating strata).

Especially in cases of stationary motors or lighting plants connected to the railroad system, there exists on the premises danger of an accidental or deliberate connection or contact with the pipe lines. It is, therefore, necessary to have strict rules regarding the return cables from such plants.

Section 5. Current Density

The above rules are intended to prevent the destruction of the pipes by electrolysis. The rate of destruction is in direct proportion to the amount of current leaving the pipe.

Any pipe line where the current leaving the pipe exceeds an average density of 0.75 milliampere per square decimeter and where this current is due to a railway, may be considered endangered by this railway, and further preventive measures must be taken.

For railways with freight service when the service is of comparatively short duration, exceptions as already mentioned are permissible.

In cases where the current leaving or passing into the pipes changes its direction, the current passing into the pipe must be taken as nil when determining the average density, until further experience has been gained in this matter.

Explanation.

Inasmuch as a total elimination of all damages to pipes would be in most cases possible only at a disproportionately high cost, which would far exceed the cost of any possible damage to the pipes, it is necessary to allow a certain limited damage, that is to say, a damage which is of little practical importance and which does not noticeably shorten the life of the pipes. These rules have therefore been compiled on the basis of the average conditions, that is to say, such as are mostly met with, and it is to be expected according to previous experience that the damage done to pipe lines by the stray currents from electrical railways generally will remain limited to the practical allowable limit wherever these rules are observed. Under exceptionally bad conditions, that it to say, under conditions which very much favor the origin of stray currents, greater corrosion of pipes in certain places can hardly be avoided, even if the limits of the drop in the potential in the rails, as laid down in Section 3, are not exceeded. It is therefore advisable to establish some measure for the elimination of immediate danger to the pipes.

For the judgment of the damage attributed to a railroad system the density of the current leaving the pipes and returning to the railroad system is indicative.

The density of the current at the pipe can be measured only after the completion of the plant. These measurements must be made during the time of operation, as per schedule, and as described in Section 3. The average density is important and is obtained from the computation of the results of several measurements, each of which follows a whole period of service.

Measurements of current density can be made, for instance, by means of a milliammeter and non-polarizable frame as designed by Prof. Haber. This frame contains two copper plates which are insulated from each other and which for the prevention of polarization are covered with a paste of copper sulphate and 20 per cent. sulphuric acid, over which a parchment soaked with sodium sulphate is laid. The frame is filled with dirt except between the plates, and placed alongside the pipe at right angles to the assumed direction of the current and then covered with dirt. A very sensitive ammeter connected to the copper plates will indicate the current passing through the frame and the density of this current can readily be calculated by taking into account the surface of the copper plates inside the frame. Inasmuch as here also only average readings are to be considered, it is advisable to use an instrument with very slow period.

According to investigations made so far, absolute danger to the pipes results whenever the density of the currents leaving the pipes reaches the average value of 0.75 milliampere per square decimeter. For railroads with small periods of operation an excess up to double and quadruple, respectively, the above value is permissible according to the rules laid down in Section 3.

Wherever the direction of the current changes, the currents entering the pipes are not to be considered in the calculations of the average density, inasmuch as it is not yet established that such currents will add to the metal of the pipes. Wherever the average values are exceeded, special precautionary measures are to be taken, the nature of which can be determined only by the local conditions. In many cases it is sufficient to protect a very limited section of the rail network, to which end the further reduction of the drop in the rails may not be necessary, but which may be attained by other means as, for instance, the re-location of short sections of tracks or pipes, or the artificial increase of the resistances between rails and pipes at such points.

In all cases the question arises whether the railroad is to be considered as the only cause of current concentration, as other causes may be found to be responsible for a part of the current on the pipes; for instance, bare neutrals or poor insulation in other electrical systems, the natural electrical elements resulting from the use of different metals in the pipe lines, or from different chemicals in solution in the ground. That part of the current which is attributable to the influence of the railroad can be determined by comparison with the measurements of the current during the period of no operation. In many cases the influence of the railroad can be judged from contemporaneous measurements of current density and the potential between pipe and rail. Under certain circumstances it is possible to find the degree of influence of the railroad and of other electrical plants operating at the same time, by establishing the course of the current in the ground. For this investigation electrodes that cannot be polarized are used as contacts from the test line to the ground. The measurements should preferably be made by the potentiometer method in order to eliminate drop at the electrodes due to the current flow, but this method is difficult in practice on account of the rapid fluctuations of the voltage. It will be sufficient in most cases to make the measurements with a voltmeter of very high resistance so that the current passing through the electrodes will be very small. It should be emphasized that such measurements should be made by experts only, as deviations from the right method which seem of no importance often give useless results.

Section 6. Control

In order to be able to test the potential at the return points of the rail system of a given territory, pilot wires are to be connected to these points and carried to a central testing place.

Before a service may be increased the potential distribution in the rail network must be retested.

The rail bonds and bridge connections are to be retested once yearly by means of a suitable rail joint tester and must be arranged so that they fulfill the rules of Sections 1 and 2. Connections, the resistance of which has been found greater than that of an uninterrupted rail of ten meters length, must be repaired to comply with these rules.

Explanation.

The control of the drop in potential in the whole network would be best assured by the installation of test wires from one of the buses to all points of probable highest and lowest rail potential, which arrangement admits of immediate measurement of potential between these points.

In certain cases, especially in existing plants, the installation of such test wires would involve great cost. Such test wire from all of the important rail points were not required; but it has been ruled that all points of the rail network, to which cables of the same district are now connected, are to be provided with test wires which have to run to some central point where readings of the differences of potentials between the return points can be taken.

Wherever the expense involved permits, it is recommended to install test wires not only to the return points, but also to the points of highest rail potentials.

After permanent changes in the operation, the distribution of the potential in the rail network is to be investigated in the same way as after the inauguration of the plant, in order to ascertain whether the new conditions still correspond to the rules.

In case of temporary changes of short duration in the whole network or parts of the same as, for instance, occasionally some festival, change or repair of tracks, fairs, exhibits, etc., no special measures are to be taken because the short duration of the influence will cause no noticeable damage even when the limits of these rules are exceeded.

The yearly investigation of the rail joints, as required by the rules, is also to be recommended with regard to the reduction of losses of energy. For these measurements an apparatus may be used which allows of the comparison of the drop in potentials across the joint with one of the adjoining uninterrupted rails so that the measurement may be taken during the operation. Joints of a resistance higher than that of an uninterrupted rail of 10 m. length are immediately to be repaired. The total resistance, as found by the measurement of the single joints, must not exceed the value which has been assumed during the projection of the plant (compare Section 2, paragraph 2).

Should it result during operation that rail joints are of a higher resistance than that assumed in the designing, it is permissible to abstain from a reconstruction of the joints as long as the permissible difference of potentials in the rails is not exceeded, even with these higher resistances. The established limits of 20 per cent. increase of the resistance of the uninterrupted rail by the bonds must not be exceeded in any case.

France—Regulations by Minister of Public Works

Circular and Order of the Minister of Public Works (France) of March 21, 1911, Establishing the Technical Conditions Which Electrical Distribution Systems Must Satisfy in Order to Conform to the Law of June 15, 1906.

Regulations Relative to the Construction of Structures for Electric Railways Using Direct Currents

Right-of-Way.

When the rails are used as conductors, all necessary measures should be taken to guard against the harmful action of stray currents, on metallic structures, such as the tracks of railways, the water and gas pipes, the telegraph or telephone lines and all other electric conductors, etc.

To this end the following regulations shall be applied:

1. The conductance of the tracks shall be known to be in the best possible condition, especially in regard to the joints, whose resistance should not exceed, in each case, that of 10 meters of the normal track.

The management is required to verify periodically this conductance and to place the results obtained on file, which shall be accessible to the administration upon demand.

2. The drop in potential in the rails, measured upon a length of track of 1 kilometer taken arbitrarily upon any section of the system, should not exceed an average value of 1 volt for the operating period of the normal car schedule.

3. The feeders tied into the track shall be insulated.

4. Where the tracks contain switches or crossings, the conductance shall be maintained by special work.

5. When the track crosses a metallic structure, it should be electrically insulated, as much as possible, throughout the length of the structure.

6. As long as no metallic structure is in the neighborhood of the tracks, a drop in potential greater than that fixed in paragraph 2 may be allowed, upon the condition that no damage will result, and particularly no trouble to telegraphic or telephonic communication, and none to railway signals.

7. The owner of the distribution system shall be required to make the installations necessary to enable the administration to verify the fulfillment of the provisions of this article; it should particularly provide, whenever necessary, for pilot wires to be installed between designated points of the distribution system.

Protection of Neighboring Aerial Lines.

At all points where the lines feeding the traction system cross other distribution lines, or telegraph or telephone lines, the supports should be established with a view to protect mechanically these lines against contact with the aerial conductors feeding the traction system.

In all cases, measures shall be taken to prevent the trolley wire touching the neighboring lines.

England—British Board of Trade Regulations.

Regulations Made by the Board of Trade Under the Provisions of Special Tramways Acts or Light Railway Orders Authorizing "Lines" on Public Roads; for Regulating the Use of Electrical Power; for Preventing Fusion or Injurious Electrolytic Action of or on Gas or Water Pipes or Other Metallic Pipes, Structures or Substances; and for Minimizing as Far as Is Reasonably Practicable Injurious Interference with the Electric Wires, Lines, and Apparatus of Parties Other than the Company, and the Currents Therein, Whether Such Lines Do or Do Not Use the Earth as a Return.

First made, March, 1894.
Revised, April, 1903.
Further revised, August, 1914.
Further revised, May, 1918.
Further revised, April, 1910.
Further revised, September, 1912.

REGULATIONS

1. Any dynamo used as a generator shall be of such pattern and construction as to be capable of producing a continuous current without appreciable pulsation.

2. One of the two conductors used for transmitting energy from the generator to the motors shall be in every case insulated from earth, and is hereinafter referred to as the "line"; the other may be insulated throughout, or may be uninsulated in such parts and to such extent as is provided in the following regulations, and is hereinafter referred to as the "return."

NOTE.—The Board of Trade will be prepared to consider the issue of regulations for the use of alternating currents for electrical traction on application.

3. Where any rails on which cars run or any conductors laid between or within three feet of such rails form any part of a return, such part may be uninsulated. All other returns or parts of a return shall be insulated, unless of such sectional area as will reduce the difference of potential between the ends of the uninsulated portion of the return below the limit laid down in Regulation 7.

4. When any uninsulated conductor laid between or within three feet of the rails forms any part of a return, it shall be electrically connected to the rails at distances apart not exceeding 100 feet by means of copper strips, having a sectional area of at least one-sixteenth of a square inch, or by other means of equal conductivity.

5. (*a*) When any part of a return is uninsulated it shall be connected with the negative terminal of the generator, and in such case the

negative terminal of the generator shall also be directly connected, through the current-indicator hereinafter mentioned, to two separate earth connections which shall be placed not less than 20 yards apart.

(*b*) The earth connections referred to in this regulation shall be constructed, laid and maintained, so as to secure electrical contact with the general mass of earth, and so that, if possible, an electromotive force, not exceeding four volts, shall suffice to produce a current of at least two amperes from one earth connection to the other through the earth, and a test shall be made once in every month to ascertain whether this requirement is complied with.

(*c*) Provided that in place of such two earth connections the Company may make one connection to a main for water supply of not less than three inches internal diameter, with the consent of the owner thereof, and of the person supplying the water, and provided that where, from the nature of the soil or for other reasons, the Company can show to the satisfaction of the Board of Trade that the earth connections herein specified cannot be constructed and maintained without undue expense, the provisions of this regulation shall not apply.

(*d*) No portion of either earth connection shall be placed within six feet of any pipe except a main for water supply of not less than three inches internal diameter, which is metallically connected to the earth connections with the consents hereinbefore specified.

(*e*) When the generator is at a considerable distance from the tramway the uninsulated return shall be connected to the negative terminal of the generator by means of one or more insulated return conductors, and the generator shall have no other connection with earth; and in such case the end of each insulated return connected with the uninsulated return shall be connected also through a current indicator to two separate earth connections, or with the necessary consents to a main for water supply, or with the like consents to both in the manner prescribed in this regulation.

(*f*) The current indicator may consist of an indicator at the generating station connected by insulated wires to the terminals of a resistance interposed between the return and the earth connection or connections, or it may consist of a suitable low-resistance maximum demand indicator. The said resistance, or the resistance of the maximum demand indicator, shall be such that the maximum current laid down in Regulation 6 (I) shall produce a difference of potential not exceeding one volt between the terminals. The indicator shall be so constructed as to indicate correctly the current passing through the resistance when connected to the terminals by the insulated wires before-mentioned.

6. When the return is partly or entirely uninsulated the Company shall in the construction and maintenance of the tramway (*a*) so separate the uninsulated return from the general mass of earth, and from any pipe in the vicinity; (*b*) so connect together the several lengths of the rails; (*c*) adopt such means for reducing the difference produced by the current between the potential of the uninsulated return at any one point and the potential of the uninsulated return at any other point; and

(*d*) so maintain the efficiency of the earth connections specified in the preceding regulations as to fulfill the following conditions, viz.:

(I) That the current passing from the earth connections through the indicator to the generator or through the resistance to the insulated return shall not at any time exceed either two amperes per mile of single tramway line or five per cent. of the total current output of the station.

(II) That if at any time and at any place a test be made by connecting a galvanometer or other current-indicator to the uninsulated return and to any pipe in the vicinity, it shall always be possible to reverse the direction of any current indicated by interposing a battery of three Leclanché cells connected in series if the direction of the current is from the return to the pipe, or by interposing one Leclanché cell if the direction of the current is from the pipe to the return.

The owner of any such pipe may require the Company to permit him at reasonable times and intervals to ascertain by test that the conditions specified in (II) are complied with as regards his pipe.

7. When the return is partly or entirely uninsulated a continuous record shall be kept by the Company of the difference of potential during the working of the tramway between points on the uninsulated return. If at any time such difference of potential between any two points exceeds the limit of *seven volts*, the Company shall take immediate steps to reduce it below that limit.

8. The current density in the rails shall not exceed nine amperes per square inch of the cross-sectional area.

9. Every electrical connection with any pipe shall be so arranged as to admit of easy examination, and shall be tested by the Company at least once in every three months.

10. The insulation of the line and of the return when insulated, and of all feeders and other conductors, shall be so maintained that the leakage current shall not exceed one-hundredth of an ampere per mile of tramway. The leakage current shall be ascertaind not less frequently than once in every week before or after the hours of running when the line is fully charged. If at any time it should be found that the leakage current exceeds one-half of an ampere per mile of tramway, the leak shall be localized and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localized and removed within 24 hours. Provided that where both line and return are placed within a conduit this regulation shall not apply.

11. The insulation resistance of all continuously insulated cables used for lines, for insulated returns, for feeders, or for other purposes, and laid below the surface of the ground, shall not be permitted to fall below the equivalent of 10 megohms for a length of one mile. A test of the insulation resistance of all such cables shall be made at least once in each month.

12. Any insulated return shall be placed parallel to and at a distance not exceeding three feet from the line when the line and return are both erected overhead, or eighteen inches when they are both laid underground.

13. In the disposition, connections, and working of feeders, the Company shall take all reasonable precautions to avoid injurious interference with any existing wires.

14. The Company shall so construct and maintain their system as to secure good contact between the motors and the line and return, respectively.

15. The Company shall adopt the best means available to prevent the occurrence of undue sparking at the rubbing or rolling contacts in any place and in the construction and use of their generator and motors.

16. Where the line or return or both are laid in a conduit the following conditions shall be complied with in the construction and maintenance of such conduit.

(*a*) The conduit shall be so constructed as to admit of examination of and access to the conductors contained therein and their insulators and supports.

(*b*) It shall be so constructed as to be readily cleared of accumulation of dust or other debris, and no such accumulation shall be permitted to remain.

(*c*) It shall be laid to such falls and so connected to slumps or other means of drainage, as to automatically clear itself of water without danger of the water reaching the level of the conductors.

(*d*) If the conduit is formed of metal, all separate lengths shall be so jointed as to secure efficient metallic continuity for the passage of electric currents. Where the rails are used to form any part of the return they shall be electrically connected to the conduit by means of copper strips having a sectional area of at least one-sixteenth of a square inch, or other means of equal conductivity, at distances apart not exceeding 100 feet. Where the return is wholly insulated and contained within the conduit, the later shall be connected to earth at the generating station or sub-station through a high resistance galvanometer suitable for the indication of any contact or partial contact of either the line or the return with the conduit.

(*e*) If the conduit is formed of any non-metallic material not being of high insulating quality and impervious to moisture throughout, the conductors shall be carried on insulators, the supports for which shall be in metallic contact with one another throughout.

(*f*) The negative conductor shall be connected with earth at the station by a voltmeter and may also be connected with earth at the generating station or sub-station by an adjustable resistance and current indicator. Neither conductor shall otherwise be permanently connected with earth.

(*g*) The conductors shall be constructed in sections not exceeding one-half a mile in length, and in the event of a leak occurring on either conductor that conductor shall at once be connected with the negative pole of the dynamo, and shall remain so connected until the leak can be removed.

(*h*) The leakage current shall be ascertained daily, before or after the hours of running, when the line is fully charged and if at any time it shall be found to exceed one ampere per mile of tramway, the leak shall be localized and removed as soon as practicable, and the running of the cars shall be stopped unless the leak is localized and removed within 24 hours.

17. The Company shall, so far as may be applicable to their system of working, keep records as specified below. These records shall, if and when required, be forwarded for the information of the Board of Trade.

Number of cars running.

Number of miles of single tramway line.

Daily Records

Maximum working current.

Maximum working pressure.

Maximum current from the earth plates or water-pipe connections (vide Regulations 6 (*k*), where the indicator is at the generating works.

Fall of potential in return (vide Regulation 7).

Leakage current (vide Regulation 16 (*h*)).

Weekly Records

Leakage current (vide Regulation 10).

Maximum current from the earth plates or water-pipe connections (vide Regulations 6 (I)) where a maximum demand indicator is used.

Monthly Records

Condition of earth connections (vide Regulation 5).

Minimum insulation resistance of insulated cables in megohms per mile (vide Regulation 11).

Quarterly Records

Conductance of connections to pipes (vide Regulation 9).

Occasional Records

Specimens of test made under provisions of Regulation 6 (II).

Board of Trade, 7,
Whitehall Gardens, S. W. September, 1912.

Spain—Electric Legislation

Law of March 23, 1900.

To prevent the return current of electric tramway lines from exercising any electrolytic effects, the following measures shall be taken:

(1) The rails of each one of the tracks are bonded by welding or by connections formed of short copper cables or of equivalent cables made of some other metal, the section of which having to exceed 100 square millimeters per track, and shall be made as large as possible.

(2) At intervals of 100 meters, or at shorter distances the tracks shall be cross-bonded.

(3) In case the official inspector should deem it necessary, a cable will have to be stretched in every line, which will have to be intimately connected with both tracks, and

(4) The dimensions of all cables and wires constituting such system will have to be calculated upon a basis that the potential difference between the generator terminals and the point of the tracks remotest from them will not exceed an amount of seven volts.

Chapter 5

ELECTROLYSIS RESEARCH

FURTHER WORK NECESSARY TO ARRIVE AT AN ENGINEERING SOLUTION OF THE PROBLEM

The Committee's conception of an engineering solution of the electrolysis problem is that the railway system and the systems of underground structures shall be so designed, constructed, maintained, and operated, that the entire problem, caused by the presence of stray currents in the earth, including corrosion of structures, fire and explosion hazards, heating of power cables, and operating losses and difficulties, is solved in the most economical way.

1. Methods of Testing.

The Research Sub-Committee of the American Committee on Electrolysis, in its investigations, has been constantly confronted with the difficulty that available methods of electrolysis testing do not yield directly, definite information as to the electrolytic condition of the affected structures. An electrolysis survey, to be conclusive, must, in some cases, show the true polarity of pipe or cable with respect to earth and in other cases it must show the actual density of the current flowing from pipe to earth in any particular locality under investigation, but to determine such polarity, or intensity of current flow, is very difficult. The existing methods of making electrolysis surveys include, among others, measurements of potential differences between pipes and earth, but such measurements, as ordinarily made, are often quite misleading. At the present time, therefore, the results that follow the application of any particular method of electrolysis mitigation are sometimes open to question because of the lack of adequate test methods. It is evident, therefore, that the development of improved means of electrolysis testing whereby the actual current density of discharge from pipes to earth at any point can be measured is an important preliminary step toward securing definite information on which the solution of the outstanding questions relating to electrolysis protection can be based. The Research Sub-Committee now has under investigation certain new methods of electrolysis testing which offer considerable promise in this direction and it is felt that a thorough study and development of these should be made in the hope of obtaining improved test methods and equipment that will facilitate securing the information required. It is desirable that these investigations precede further experimental work relating to methods of mitigation.

2. Effect of Different Rail Voltage Drops.

It is important to examine the resulting conditions, from an electrolysis standpoint, of different values of voltage drop in rails, particularly in cities or localities where such voltage drops are low, and comparable to those which correspond to maximum economy from the railway standpoint, taking due account of variations in physical conditions in different localities.

3. Studies of Electric Railway Power Distribution.

Studies should be made of the costs of various measures designed to minimize track drops in order to determine which measures, if any, are best to apply. The application of automatic and semi-automatic substations to street railways should be given consideration to determine how far the voltage drop in the rails can be reduced with such a system when developed to the economic limit. In making these cost studies track networks should be selected where the layout is both favorable and unfavorable for such installations. Studies might also be made of the joint application of insulated negative feeders and automatic substations to determine what values of voltage drops in the rails can be obtained at reasonable cost.

4. Study of Mitigative Measures Applicable to Affected Structures.

After applying mitigative measures to the railway system, it may be found that in many cases it will still be necessary to reduce further the hazards to underground structures. It is therefore important to study methods of mitigation applicable to the structures themselves, and particularly the quantitative effect of insulating joints in protecting pipes and cables and the application and maintenance of such a drainage system as will keep all underground structures negative to the earth without involving fire and explosion hazards, and assuming in both cases the railway stray current at a low value.

5. Determination of Safety Criterion for Pipes Where Positive to Earth.

At the present time there is no reliable criterion as to the actual hazard to underground pipes unless they are at all points negative or neutral to earth at practically all times. Wherever pipes are positive to earth, it is impossible with the present methods of testing to determine the actual degree of corrosion hazard. If, however, the development work in connection with methods of measuring current discharge from pipes mentioned in a preceding paragraph should result favorably, it appears probable that such test methods could be used for the purpose of establishing a fairly accurate criterion for a safe condition of underground structures. The Committee feels that this question should be investigated carefully so that anything possible of accomplishment in this direction may be realized.

6. Self Corrosion.

When iron pipes are embedded in certain soils, corrosion due to soil conditions or local galvanic action often results in greater or less degree. This phenomenon is commonly known as self-corrosion. Obviously, it is of importance to differentiate between the effects of corrosion due to the action of chemicals in the soil and that due to stray currents, in order that an intelligent procedure can be adopted for remedying the trouble. It is believed that a thorough and systematic study of the question of soil corrosion on cast iron, wrought iron and steel pipes would bring to light information that would be of great value in dealing with the electrolysis problem. Such investigations in order to be of much value should be extended over a period of years.

7. Fire and Explosion Hazards on Gas and Oil Pipes.

In addition to preventing corrosion, there is the closely related problem of protecting against fires and explosions due to electric currents on gas or oil pipes. At the present time no definite information is available as to what limiting currents can safely be permitted on such pipe systems. It is important to investigate this question, both statistically and experimentally, in order to evaluate this hazard.

8. Heating of Power Cables Due to Stray Currents on Sheaths.

In view of the fact that it is common practice to electrically drain the lead sheaths of power cables to protect them from corrosion, and since the currents on the sheaths may be of considerable magnitude, reducing the current carrying capacity of the conductors, it is important to determine the limitations that should be imposed on such currents in order not to cause serious heating, and hence undue reduction in current carrying capacity of the cables.

Summary. As the Committee now views it, a research of some magnitude is necessary to secure further information needed for an engineering solution of the problem, to comprise the following:

1. Development of practical means for measuring current density across contact surfaces of pipes and earth. Such measurements are especially necessary if structures are not kept negative to earth.

2. Development of practical means for accurately determining the polarity of structures and adjacent earth, in such a way as to eliminate galvanic effects.

3. Study of the relation of different values of voltage drop in the track to stray current from rails, including the large variations of this relation under different conditions, and the effects of such stray currents on underground utilities and railway structures.

4. Cost studies of street railway systems and different methods of power supply to determine the minimum values of track voltage drop consistent with economic operation in various locations.

5. Quantitative effect of insulating joints in protecting pipes and cables, assuming railway stray current at low values.

6. Detailed study of the application and maintenance of such a drainage system as will keep all underground structures negative to earth. Such studies to include the effect of drainage on corrosion of subsurface and railway structures and its effect on producing fires and explosions.

7. Comparison of 5 and 6.

8. Investigation of the distribution of current flowing from pipe to adjacent earth for the purpose of determining whether a diversity

factor can be established, *i. e.,* the relation between maximum and average current density.

9. Continuing study of joint corrosion.

10. Study of soil and galvanic corrosion with particular reference to differentiating them from the effects of stray currents.

11. Setting limit of current on gas and oil pipes to avoid fire and explosion hazard.

12. Setting limit of current on power cable sheaths to avoid overheating.

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APPENDIX

TABLE 5

CURRENT DATA FOR STEEL RAILS*

Based on a resistivity of 0.0003 ohm per pound-foot, this being equivalent to about 11 times the resistivity of copper.

Weight (lbs. per yd.)	Current for 1 m. v. on 1 ft. (amperes)	Weight (lbs. per yd.)	Current for 1 m. v. on 1 ft. (amperes)
60	66.7	110	122.0
65	72.2	115	128.0
70	77.8	120	133.0
75	83.3	125	139.0
80	88.9	130	144.0
85	94.4	135	150.0
90	100.0	140	156.0
95	106.0	145	161.0
100	111.0	150	167.0
105	117.0		

* Does not include rail joints.

TABLE 6A

CURRENT DATA FOR PIPES

CAST IRON

Nominal inside diameter (inches)	A.W.W.A. standard Class A		A.W.W.A. standard Class B	
	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)
3	13.04	10.6	14.60	11.9
4	18.03	14.7	20.06	16.4
6	27.90	22.7	31.14	25.4
8	38.74	31.6	42.68	34.8
10	51.95	42.3	58.80	47.9
12	66.90	55.0	76.44	62.0
14	82.33	67.0	94.82	77.0
16	98.75	81.0	114.70	94.0
18	118.10	96.0	137.70	112.0
20	137.2	112.0	163.20	133.0
24	186.5	152.0	217.10	177.0
30	265.1	216.0	312.60	255.0
36	357.8	292.0	419.00	341.0
42	465.6	379.0	541.50	441.0
48	607.7	495.0	688.50	562.0
54	730.2	596.0	842.80	685.0
60	835.6	680.0	1,012.00	826.0
72	1,169.0	952.0	1,416.00	1,150.0
84	1,141.0	1,177.0	1,860.00	1,515.0

TABLE 6A (*Continued*)
CAST IRON

Nominal Inside Diameter (inches)	A.W.W.A. standard Class C.		A.W.W.A. standard Class D.	
	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)
3	15.47	12.6	16.37	13.2
4	21.27	17.3	22.83	18.5
6	32.93	26.8	35.30	28.8
8	47.97	39.1	51.16	41.7
10	65.66	54.0	71.54	58.0
12	85.26	70.0	93.59	76.0
14	108.0	88.0	119.1	97.0
16	133.3	109.0	147.5	120.0
18	162.4	132.0	178.4	145.0
20	190.9	156.0	212.4	173.0
24	257.7	210.0	286.2	233.0
30	367.5	300.0	421.4	344.0
36	499.8	407.0	580.7	474.0
42	656.6	535.0	762.0	621.0
48	833.0	680.0	960.4	780.0
54	1,041.0	848.0	1,227.0	1,000.0
60	1,220.0	990.0	1,458.0	1,190.0
72	1,744.0	1,430.0		

TABLE 6A (*Continued*)
CAST IRON

Nominal inside diameter (inches)	New England W.W.A. standard Class A.		New England W.W.A. standard Class B.	
	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)
4	14.89	12.1	....	....
6	24.32	19.9	....	....
8	35.58	29.0	....	....
10	49.04	40.0	52.03	42.4
12	61.14	50.0	65.92	54.0
14	76.85	63.0	82.41	67.0
16	90.98	74.0	98.95	81.0
18	104.5	85.0	115.2	94.0
20	121.9	99.0	133.7	109.0
24	155.6	127.0	174.4	142.0
30	215.3	176.0	244.8	200.0
36	287.0	234.0	326.0	266.0
42	368.4	300.0	422.1	344.0
48	459.3	374.0	530.2	432.0
54	559.8	456.0	650.3	530.0
60	664.0	541.0	782.3	640.0

TABLE 6A (*Continued*)

CAST IRON

Nominal Inside Diameter (inches)	New England W.W.A. Standard Class C.		New England W.W.A. Standard Class D.	
	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)
4	15.7	12.8	....	....
6	26.72	21.8	....	....
8	40.38	32.9	....	....
10	54.99	44.8	57.94	47.2
12	70.67	58.0	75.39	61.0
14	87.97	72.0	94.85	77.0
16	106.9	87.0	114.8	93.0
18	127.4	104.0	138.0	112.0
20	147.6	120.0	161.4	132.0
24	196.3	160.0	215.3	175.0
30	277.7	226.0	307.3	250.0
36	373.3	304.0	412.3	336.0
42	481.1	392.0	538.9	439.0
48	608.0	495.0	678.9	552.0
54	749.5	610.0	839.9	684.0
60	911.5	740.0	1,029.7	840.0

TABLE 6B
STEEL PIPE

Nominal inside diameter (inches)	Standard		Extra Strong	
	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)	Weight pounds per foot	Current for 1 mv on 1 ft. (amperes)
0.125	0.24	1.11	0.31	1.44
0.25	0.42	1.95	0.54	2.50
0.375	0.57	2.64	0.74	3.43
0.50	0.85	3.94	1.09	5.0
0.75	1.13	5.2	1.47	6.8
1.00	1.68	7.8	2.17	10.1
1.25	2.27	10.5	3.00	13.9
1.50	2.72	12.6	3.63	16.8
2.00	3.65	16.9	5.02	23.3
2.50	5.79	26.8	7.66	35.5
3.00	7.58	35.1	10.25	47.5
3.50	9.11	42.2	12.51	58.0
4.00	10.79	50.0	14.98	69.0
4.50	12.54	58.0	17.61	82.0
5.00	14.62	68.0	20.78	96.0
6.00	18.97	88.0	28.57	132.0
7.00	23.54	109.0	38.05	176.0
8.00	24.70	114.0	43.39	201.0
8.00	28.55	132.0	....	....
9.00	33.91	157.0	48.73	226.0
10.00	31.20	145.0	54.74	254.0
10.00	34.24	159.0	....	....
10.00	40.48	188.0	....	....
11.00	45.56	211:0	60.08	278.0
12.00	43.77	203.0	65.42	303.0
12.00	49.56	230.0	....	....
13.00	54.57	253.0	72.09	334.0
14.00	58.57	271.0	77.43	359.0
15.00	62.58	290.0	82.77	383.0

TABLE 6C
WROUGHT IRON PIPE

Nominal Inside diameter (inches)	Standard		Extra Strong	
	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)
0.125	0.24	1.15	0.29	1.39
0.25	0.42	2.01	0.54	2.58
0.375	0.56	2.68	0.74	3.54
0.50	0.84	4.02	1.09	5.2
0.75	1.12	5.4	1.39	6.6
1.0	1.67	8.0	2.17	10.4
1.25	2.25	10.8	3.00	14.3
1.50	2.69	12.9	3.63	17.4
2.0	3.66	17.5	5.02	24.0
2.50	5.77	27.6	7.67	36.7
3.0	7.54	36.0	10.25	49.0
3.50	9.05	43.3	12.47	60.0
4.0	10.72	51.0	14.97	72.0
4.50	12.49	60.0	18.22	87.0
5.0	14.56	70.0	20.54	98.0
6.0	18.76	90.0	28.58	137.0
7.0	23.41	112.0	37.67	180.0
8.0	25.00	120.0	43.00	206.0
8.0	28.34	136.0	....	....
9.0	33.70	161.0	48.73	233.0
10.0	32.00	153.0	....	....
10.0	35.00	167.0	....	....
10.0	40.00	191.0	54.74	262.0
11.0	45.00	215.0	60.08	287.0
12.0	45.00	215.0	....	....
12.0	49.00	234.0	65.42	313.0

TABLE 6D

A. G. I Standard Gas

Nominal inside diameter (inches)	Weight pounds per foot	Current for 1 mv. on 1 ft. (amperes)
4	17 3	14 1
6	27 3	22.2
8	38 0	30 9
10	51 0	41.5
12	67 0	55 0
16	102.0	83 0
20	139.0	113 0
24	186.0	152.0
30	256.0	209.0
36	346.0	282 0
42	453 0	369 0
48	610 0	495 0

TABLE 6E

LEAD PIPE

Specimen No.	Card diameter (inches)	Card weight (lbs. per ft.)	Current for 1 mv. drop per foot (amperes)
1	0.25	0.5	0.915
2	25	.5	.908
3	25	.5	.942
4	.75(AA)	3.5	7.257
5	.75(AA)	3.5	7.332
6	.75(AA)	3.5	7.305
7	.75(AA)	3.5	7.123
8	.75(AA)	3.5	7.148
9	.75(AA)	3.5	7.067
10	1.00(C)	2.5	4.914
11	1.00(C)	2.5	4.921
12	1.00(C)	2.5	4.958
13	1.00(AA)	4.75	9.785
14	1.00(AA)	4.75	9.833
15	1.00(AA)	4.75	9.766
16	2.00(C)	6.0	11.81
17	2.00(C)	6.0	11.78
18	2.00(C)	6.0	11.77
19	2.00(AA)	9.0	18.14
20	2.00(AA)	9.0	18.11
21	2.00(AA)	9.0	18.11
22	.25	.5	.915
23	.25	.5	.913
24	.25	.5	.915
25	.75(C)	1.75	3.302
26	.75(C)	1.75	3.343
27	.75(C)	1.75	3.322

Sample Data Sheets

Time	Date.....Tested by.... Location............. Ave. or St.............	Potential, cable to												Direction of current on cable	Electrolysis pittings on cable?	Cables bonded together?	Water in manhole?	Duct material?	Cables protected?	Cables supported?
				Duct		Water		Gas		Track										
		+	−	+	−	+	−	+	−	+	−	+	−							
1130																				

CURRENT MEASUREMENTS

(This shows a condensed form in convenient size for a field notebook.)

DATE AND TIME		Duration of Test Min.	Dist. betw. points Feet	Amp. per Millivolt K	Drop—Millivolts			Current—Amperes			DIRECTION
					Max.	Min.	Ave.	Max.	Min.	Ave.	

POTENTIAL MEASUREMENTS

DATE AND TIME		Duration of Test Min.	Potential—Volts Max.	Potential—Volts Min.	Potential—Volts Ave.	Momentary bond Current Amp.

Potential Survey:—

City:— Date:— Observer:—

Time	Location	Measurements		Duration of Test Min.	Volts Polarities Refer to (A)			Max. Momentary Current Through Temporary Bond	Remarks
		From (A)	To (B)		Max.	Min.	Ave.		

Current Survey:—

City:— Date:— Observer:—

Time	Location	Size and kind of pipe	Dist. bet. contacts feet	Duration of test min.	Direction of current flow	Drop in millivolts			Calculated current amperes			Remarks
						Max.	Min.	Ave.	Max.	Min.	Ave.	

Data sheet for Electrolysis Survey.

TESTS ON EXPOSED PIPE

City:— Date:— Time:— Observer:—

Location:—

Size and kind of pipe:—

Pavement:— Soil:—

Location of nearest trolley tracks:—

Location of nearest trolley power station:—

Approximate age and condition of pipe:—

	Max.	Min.	Aver.	Potential to Other Pipes, Etc.:—
Duration of each test........minutes				
Potential, pipe to rails, volts	......	......	......	
Current through temporary bond connection, amperes			......	
Distance between contacts on pipe = ...feet				
Drop on pipe, millivolts	....	......	......	
Current on pipe, amperes	......	......	......	
Direction of current flow:—				

Simultaneous Drop Measurements for Resistance of Joints.

		Equivalent resistance Feet of pipe.	Ohms.
Drop in ....feet of pipe =	millivolts		
Drop across first joints	millivolts	....	....
Drop across second joint =	millivolts	....	....

THE FLAT DISK CENTER FOR TURNTABLES

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In this paper are set forth the merits of a flat disk center for turntables, with grease as a lubricant. Diagrams of energy consumption, taken in December, 1920, and a detail plan of the center are shown. An attempt is made to separate, approximately, the friction losses in the center from the losses in the tractor.

In Volume 17 of the Proceedings, Appendix F, are shown diagrams and tabulations of energy consumption for various centers; the experiments for them were made in May, 1915. Item 2, of the tabulation, pertains to the center under discussion in this paper.

The flat disk center was installed late 1913. It has been in service (and is still) for seven years. It has given excellent results and should be good for many years more. About forty engines a day are turned. It will thus be seen that the center has been thoroughly tried. It can now be judged in the light of experience.

Quite complicated centers are in use, mostly of the roller kind, running in oil. The roller center has many parts. It is probable that, in the most carefully fabricated roller center, the load is not equally distributed among the rollers, and it is certain that this condition soon arises under service. Some designs have a large segment of a cylinder for centering and distributing the load; such devise is inadequate. The centering can be done accurately only through a pin.

I found the roller center difficult to maintain and inspect, and that, under present heavy loads and frequent service, it gave trouble.

The stock argument for the roller center is the low energy consumption as compared with the disk center. It is the intention to refute this argument.

Lenticular disk centers, sliding in oil, are also used. The advantages of a lenticular disk are not apparent. Why lenticular?

A center, running in oil, is not self-cleaning! and the devises for retaining the oil and keeping out the dirt, complicate the design. Simplicity of design makes for continuity of service and ease of maintenance.

In the flat disk center, as developed by me, the annual maintenance cost is very nearly nothing. It is not necessary to clean the center, or open it up, as must be done for roller centers to pick out the broken thrust washers of the conical rollers, and to make repairs.

On account of the present heavy engine loads, it is difficult to keep the load, a linear inch of roller, within safe working limits; special steel is used for the high loading. But even such precautions are insufficient and add to the cost.

The drawing for the flat disk center is clear, but it is well to call attention to some of the features. The load is accurately centered through a pin. The grease grooves are large, have rounded corners and are cut on the upper sliding surface. The phosphor-bronze disk is without grooves and is swept by the lubricant at every rotation. The lubricant is forced by compression screw cups, with handles, through the feed pipes and center. A grease gun may be used.

The following instructions are issued to the turntable attendant:

Rules for Lubricating Disk Centers of Turntables

1. Use cup graphite grease, soft consistency. Do not use oil or other greases.

2. Keep the grease cups, ducts and grooves filled with grease.

3. Screw compression grease cups should be used. One cup should be installed at one end of the pipe or duct; the opposite end of the duct should have a screw cap.

4. To lubricate the disc, unscrew the screw cap and then turn the screw lid of the compression cup until grease oozes out of the open end. Do this once a week or oftener, depending on the number of times a day the table is used.

5. It is necessary to keep the grease in a soft condition. If allowed to remain too long in the grooves and ducts, it will cake or harden. Hence, another reason for Rule 4.

6. While the grease is being compressed, the turntable should be rotated. (No engine on table.)

7. If the grease does not ooze out of the open end, attempt to clean the ducts and grooves with a wire, removing all caked crease. If it is impossible to clean the duct, etc., with a wire, the table must then be lifted and grooves cleaned.

It is essential that the lubricant be kept plastic. It must not be allowed to harden or cake.

Several flat disk centers are now in use on the New York Central Lines. In one case, attention was not given to proper lubrication. A yellow grease was used. The grease caked. It was necessary to lift the table so that the center could be cleaned. Graphite grease, of soft consistency, gives excellent results.

For the disk, subject of this paper, graphite grease was used.

Trunnion bascule bridges are now in successful service. The trunnion lubricant is grease. There is every reason for a disk being as practicable as a trunnion: both slide and can be similarly lubricated.

Coming now to the energy consumption, a properly designed and lubricated sliding surface improves with service; the friction decreases through use. In three years' time, the frictional torque on the motors of one of the Calumet River lift bridges of the New York Central Railroad decreased from 940 ft. lb. to 600 ft. lb. A marked decrease in the friction of the flat disk center will also be found.

The input of energy to the tractor (this is what the railroad pays for) is used for three purposes: (1) to overcome the friction in the center; (2) to overcome the friction of the tractor; and (3) to cover the electric losses in the tractor. The last two items represent the total loss in the tractor. A particular value of this total loss, I have called M in Table I. M is defined as the loss in the tractor on the supposition of a frictionless center. It is an ideal value, and it can be calculated from the test data as will be shown. The actual loss in a tractor is always greater than M because the pull, necessary to move the table, increases the losses in the tractor. It is not possible to calculate the exact value of the pull of the tractor.

The use of M, in place of the actual losses in the tractor, penalizes the center, as the calculated losses in the center are somewhat greater than the actual losses.

In Table 1 are given the energy consumption figures for the flat disk and the tractor. The basic figures are taken from Volume 17 of the Proceedings, item 2, and the wattmeter diagrams accompanying this article. The interval of time between the sets of tests is more than five years. The figures are for friction losses in the center, and all losses in the tractor.

TABLE 1—ENERGY CONSUMPTION FOR FLAT DISK CENTER

KW.-Minutes		Total Weight on Center		KW.-Minutes	
M	Input to Tractor	Pounds		Input to Tractor	M
Year 1915			Year 1920		
....	4.32	166000	166000	1.53	....
2.85	6.98	470500	411500	2.00	1.21
			556000	2.10	1.22
2.78	8.27	589700	604600	2 13	1.26
2.81	19.57	1226200	1738100	7.76	1.27
1	2	3	4	5	6

Average M, 2.81 Average M, 1.24

Throughout this article, the figures and data of energy consumption are for 360 degrees of rotation of the turntable at a constant velocity. For this condition, the input of energy balances the loss of energy.

The calculation of M will now be shown. The loss in the tractor in excess of M, is in proportion to the pull of the tractor on the table. The pull on the table is in proportion to the load on the center. Hence, the excess losses are proportional to the loads on the center. These statements are strictly true for all friction losses, and are nearly true for the electric losses. Unvarying coefficients of friction, for any particular test, are assumed.

Referring to Table 1, 1920 tests, the following equations are written:
166000p + M = 1.53.

1738100p + 4M = 7.76 in which p is the proportional factor. The terms, with the p factor, represent the excess losses. The solution of the equations gives M equal to 1.27 kw.m. The other values of M, shown in columns 1 and 6, were calculated similarly.

When the uncertainty of the engine loads is considered, the nearly equal values of M are remarkable. An average value of 1.24 kw.m. will be used for the remaining discussion.

Referring again to the article in Volume 17 of the Proceedings, I have calculated all the values of M for the tests. For the purpose of making comparisons with the roller center, Table 2, showing values of M and other matter, is presented.

Table 2—Energy Consumption Figures for Roller Centers

Item or Test	Weight in Pounds on Center	KW.-Minutes		
		Total Input	M	Loss in Center
1	127000	1.77	1.50	0.27
3	181100	4.24	3.36	0.88
4	181100	2.20	1.73	0.47
5	115000	1.80	1.45	0.35
7	124183	6.94	6.30	0.64
	728383			2.61

Summarizing, a total load of about 728,000 lb. was turned with a loss in the roller centers of 2.61 kw.m. The loss of 100,000 lb. is 0.35 kw.m. From the Table, I selected the weights of the turntables only, for the loads.

Referring to Table 1, the loss in the flat disk center for a load of 166,000 lb. is 1.53—1.24=0.29 kw.m. For 100,000 lb., the loss is 0.17 kw.m.

The flat disk center is now more efficient than the best roller center, item 1, of Table 2. At the time the roller center was tested, in 1915, it was new and in excellent condition. The disk center was also new, but its friction losses were high. By giving regular and proper attention to the lubrication, the losses in the disk center, for a load of 166,000 lb., are reduced from 1.51 kw.m. to 0.29 kw.m. The tractor losses were, also, greatly reduced. See Table 1.

The coefficient of friction, f, for the disk center will now be calculated. The disk is 24 inches in diameter. The frictional resistances are assumed as acting in a circular path of a diameter 16 inches and a length of 4.2 ft. The equation is (4.2) (166000) f = 12760. f = 0.0183. The right side of the equation is the equivalent in foot pounds of 0.29 kw.m. Taking the total weight of 1738100 lb. and the corresponding total losses for the center, 2.80 kw.m., f equals 0.1169. In 1915, the coefficient of friction obtained by a similar calculation was 0.086.

I will again calculate f by a crude method. A Mallet engine was placed on the table, and given an angular velocity of 360 degrees a minute. The power was then cut off. The table, with its load, drifted through 360 degrees and came to a stop in about 120 seconds. The total load on the center was 680,000 lb. The retarding forces are the friction on the disk and the drag of the tractor. The disk friction has an arm of two-thirds of a foot; the tractor drag, 43½ feet.

The drag of the tractor will now be considered. After the power is cut off, the tractor is retarded by its own friction. The tractor also has kinetic energy, due to rotation of its parts and its translation as a body. The kinetic energy overcomes part of the friction. The remaining friction must be balanced by the pull of the table on the tractor.

It is very difficult to calculate the kinetic energy of the tractor, but its friction losses, for a frictionless center, have already been calculated. The quantity M covers the losses. M is equal to 1.24 kw.m., or 54560 ft. lb. The tractor moved through a distance of 273 feet, the length of the path around the turntable pit. Hence, the drag on the tractor must be no greater than 200 lb.; it may be considerably less. I will calculate f by, first, neglecting the drag and, second, by considering it.

A Principle of Mechanics.—The sum of the moments of the retarding forces acting on a rotating body equals the moment of inertia of the body about the axis of rotation times the angular retardation.

The angular retardation, using the second as the unit of time, is six degress divided by 120, or 0.05 degrees, or 0.0009 radians.

The moment of inertia may be taken equivalent to that of a rigid body 75 ft. long, six and a half wide, and weighing 680000 lb. The mass is 21120. The rigid body is an approximate substitute for the combined table and engine. Using these numbers, the moment of inertia is found to be 10000000 closely.

All of the quantities necessary for applying the principle of mechanics are now known. The equation is:

$$\frac{2}{3}(680000)\,f = (10000000)\,(0.0009). \quad f \text{ equals } 0.019.$$

The left hand side is the sum of the moments of the retarding forces acting on the table and engine. The right hand side contains the equivalent moment of inertia, and the angular retardation. Considering the greatest drag of the tractor, the equation becomes:

$$\frac{2}{3}(680000)\,g + (200)\,(10000000)\,(0.0009). \quad f \text{ equals } 0.0006.$$

The approximations of this method are such as to penalize the center. Both methods show a low coefficient of friction.

The drifting of the heavy engine, through an angular distance of 360 degrees is an indication of low friction losses in the center and tractor. The drifting test is a rough and ready way of determining the efficiency of a center and tractor.

The cost of power for turning an engine on a flat disk is very small. Referring to Table 1, the cost for turning any of the engines did not exceed one-eighth of a cent with power at 3 cents a kw.-hr. Really, the power cost is a very small item for the usual center, disk or roller. Hence, a center which is low in first cost and maintenance, is the most desirable. A simple flat disk meets the requirements.

Now, how about turning by hand? If the table is at a point where only a few turns a day are made, a roller center is desirable for hand power. Although, a well-worn and lubricated disk center will answer as well. A new disk center would not receive enough wear to make it smooth. But wherever a tractor is used, I see no economy in a roller center. If there is a failure of power, the resistances are too great for hand operation, if the tractor is allowed to remain attached to the table.

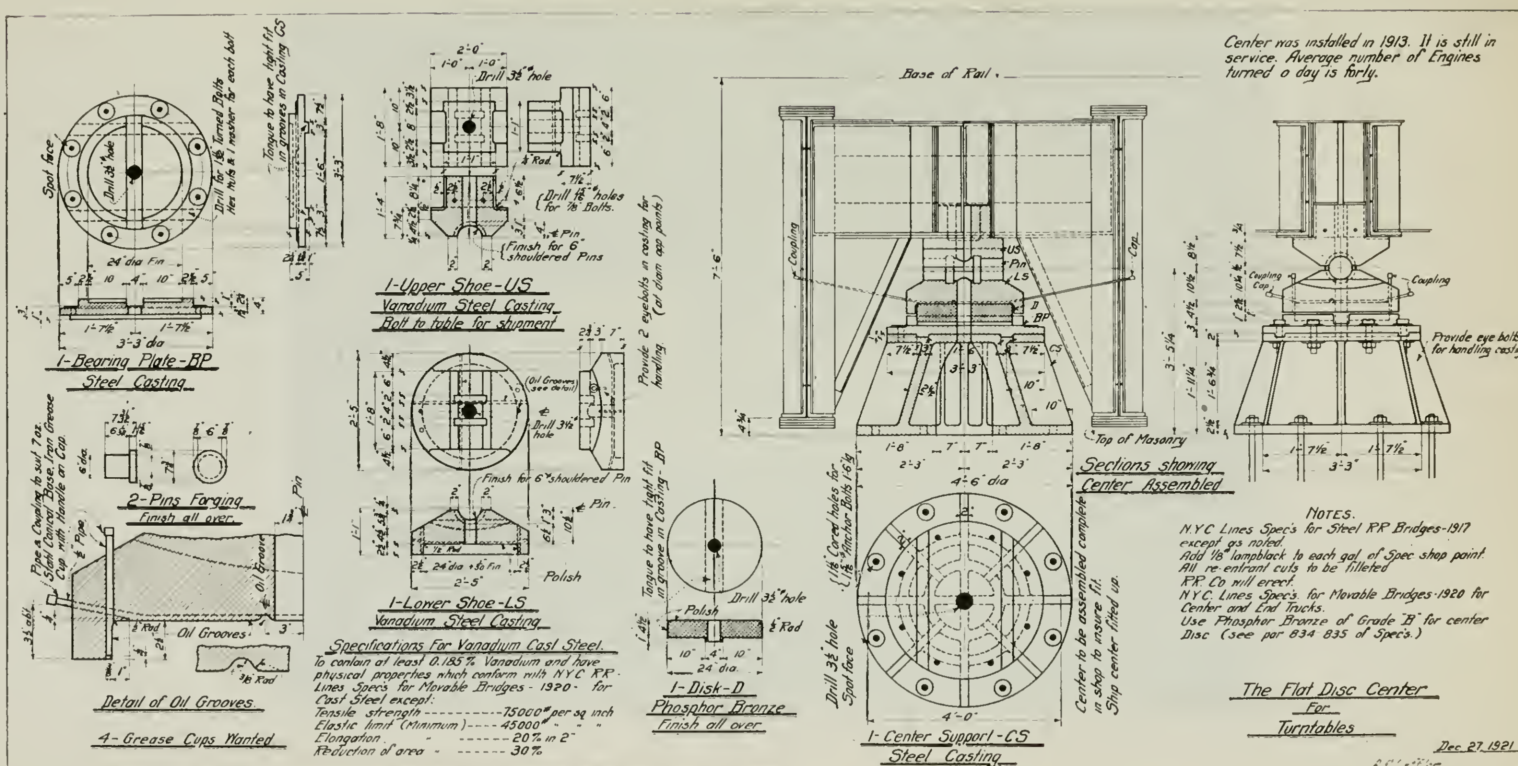
The experiments show very clearly the relative great loss in the tractor. It is easily seen why it is difficult to turn, by hand, a table with the tractor attached.

A short time ago, I made an examination of a flat disk center which had been in service, for three years, at a point where about 100 engines a day were turned. The disk was very smooth; there was scarcely any wear.

I have modified the design of the disk center. The thickness of the disk has been reduced to 2½ inches. Other minor changes were made. The pedestal has been made lower. Recent bids for the modified design are as low as $400.00.

If any trouble arises in a properly designed flat disk center, it will be found due to a lack of a little common sense. This sense should be applied with the lubricant.

Why use a complex devise, like a roller center, when a simple disk is more economical?



Center was installed in 1913. It is still in service. Average number of Engines turned a day is forty.
Base of Rail
Sections showing Center Assembled
Top of Masonry
Provide eye bolts for handling casting
Coupling
Coupling Cap
Cap
1-Bearing Plate-BP
Steel Casting
Spot face
Drill 3½" hole
Drill for 1⅛" Turned Bolts Hex Nuts & 1 washer for each bolt
Tongue to have tight fit in grooves in Casting CS
1-Upper Shoe-US
Vanadium Steel Casting
Bolt to table for shipment
Drill 1⅛" holes for ⅞" Bolts.
Finish for 6" shouldered Pins
1-Lower Shoe-LS
Vanadium Steel Casting
Finish for 6" shouldered Pin
Polish
Provide 2 eyebolts in casting for handling. (at diam opp points)
2-Pins Forging
Finish all over.
Pipe & Coupling to suit 7 oz. Stahl Conical Base. Iron Grease Cup with Handle on Cap.
Oil Grooves
Detail of Oil Grooves.
4-Grease Cups Wanted
Specifications For Vanadium Cast Steel.
To contain at least 0.185% Vanadium and have physical properties which conform with NYC RR. Lines Specs for Movable Bridges - 1920 - for Cast Steel except:
Tensile strength ---------- 75000# per sq inch
Elastic limit (Minimum) ---- 45000# " " "
Elongation " ------ 20% in 2"
Reduction of area " ------ 30%
Tongue to have tight fit in groove in Casting - BP
1-Disk-D
Phosphor Bronze
Finish all over
Drill 3½" hole
Spot face
{1⅛" Cored holes for 1⅛" Anchor Bolts 1'-6½"
1-Center Support-CS
Steel Casting
Center to be assembled complete in shop to insure fit. Ship center fitted up.
NOTES.
N.Y.C Lines Spec's for Steel RR Bridges-1917 except as noted.
Add 1/8" lampblack to each gal. of Spec shop paint.
All re-entrant cuts to be filleted
RR Co will erect.
N.Y.C. Lines Spec's. for Movable Bridges-1920 for Center and End Trucks.
Use Phosphor Bronze of Grade "B" for center Disc (see par 834 835 of Spec's.)
The Flat Disc Center For Turntables
Dec 27 1921

John Findley Wallace

John Findley Wallace

A MEMOIR

John Findley Wallace was born at Fall River, Massachusetts, September 10, 1852. His parents were the Rev. David A. Wallace and Martha J. Wallace. When but a child he was taken on the then difficult journey from Fall River to Monmouth, Illinois, where his father had been sent to found a college under the auspices of the United Presbyterian Church.

It was in this environment of college culture—surrounded by the rawness and the bigness of the struggle of the early settler for conquest over the virgin prairie—that the young man received the training which has been manifest throughout his career.

While ever a leader in the technique of his chosen profession, he was held in affectionate remembrance by the laborer, the mechanic, the foreman or the superintendent, with whom he came in contact as builder or operator. He put into his work a wealth of enthusiasm and energy—often to the discomfort of his subordinate—for his basic motto was to pay no attention to the clock, and the word "cannot" never appealed to him.

His work in American railroading has been fundamental. It was his good fortune to be identified with some of the early railroad enterprises in the Middle West, when it was possible to be in touch with all phases of the industry. Thus he was, alternately surveyor, engineer, constructor and operator on the same railroad, and this at a time when the prime consideration was to make the dollar go as far as possible. It was accomplishments such as his that made possible the development of our Middle West.

In 1869, Mr. Wallace entered the service of the Carthage & Quincy Railroad as rodman. In 1870 he was Assistant Engineer of Surveys of the Quincy, Alton & St. Louis Railroad. From 1871 to 1876 he was Assistant Engineer in United States Engineering Corps at Rock Island, Ill. During that time he was also engaged in private surveys and other important work, one of which was excavation of a channel through the St. Louis chain of rocks by machinery of his own design and construction and by day labor, personally supervised by him. It is interesting to note that a previous attempt had been made to excavate the channel through this particular chain of rocks by the United States Government earlier in the century, but submarine blasting carried on at that time was unsuccessful. He also removed the foundation of the original Rock Island bridge, the first bridge constructed across the Mississippi River.

In 1879 Mr. Wallace was appointed Chief Engineer of the Peoria & Farmington Railway, of which he had charge of location, construction and operation from Peoria to Keithsburg. Later this road was consolidated with the Iowa Central, and Mr. Wallace had charge as Master of Trains. At the same time he was Engineer in charge of construction and improvements on this line, one interesting piece of work being the construction of a transfer over the Mississippi River at Keithsburg.

During the fall and winter of 1886 he was Assistant Engineer of surveys and other work on the Union Pacific Railroad in the Rocky Mountains.

His next effort was in the field of bridge engineering, where he made a reputation for himself in technical skill and construction resourcefulness in the construction of the Sibley bridge across the Missouri River, and a bridge across the Mississippi River near Fort Madison. He also had charge of a system of river abutments and improvement work on the Missouri River above the Sibley bridge. Subsequently he was connected with E. L. Corthell in general engineering work, with headquarters at Chicago, his principal work at that time being the construction of the joint entrance of the Santa Fe and Illinois Central into Chicago from the West, together with improvements of the Chicago & Alton terminal entrance. Mr. Wallace also made examinations and plans of various railroad projects and reported on plans and estimates for a bridge at New Orleans over the Mississippi River. Before this work was completed, Chicago was giving thought to the World's Fair. The Illinois Central had a serious problem in how to handle the traffic that would result from the Fair, and Mr. Wallace's suggestion to the management of the Illinois Central resulted in his being retained by that railroad as Chief Engineer to plan and put into execution the suburban service which so successfully handled the World's Fair crowds and has ever since been an important factor of transportation in Chicago. The elevation of tracks in the City of Chicago and the Lake Front improvement were not only under Mr. Wallace's general supervision, but he also assisted in the negotiations with the City which made this work possible. He also constructed extensive terminals in the City of New Orleans, planned and constructed the Stuyvesant Docks at New Orleans and extensive terminals at Harahan Yards, near New Orleans; also the improvement of terminals at East St. Louis, Louisville and Memphis.

In the fall of 1897 Mr. Wallace resigned as Chief Engineer of the Illinois Central Railroad to accept the position of Vice President and General Manager of the Mathison Alkali Works, of Saltville, Virginia, and while in that capacity was President of a proposed railroad known as the Saltville and Virginia Railroad.

He returned to the Illinois Central Railroad January 1st, 1898, as Assistant Second Vice President, with general supervision over the Engineering Department and of matters connected with the operation of the System. During this time he had personal charge of the construction of the Fort Dodge & Omaha Railroad, 132 miles in length, which gave the Illinois Central an entrance into Omaha and Council Bluffs. This road, which by its efficient and economical operation has proved its good location and construction, was located and constructed and was in full and successful operation within a single year. He also had charge of negotiations and construction of the St. Charles Air Line from Chicago. The knitting together of the different lines which go to make up the Illinois Central System into one homogeneous transportation machine, was one of Mr. Wallace's great accomplishments. January 1, 1901, Mr. Wallace was appointed Assistant General Manager in charge of operation, having in charge the Engineering, Roadway, Transportation, Machinery and other departments, classified under the head of operation.

September, 1902, he was appointed General Manager of the Illinois Central Railroad.

In 1904 Mr. Wallace left the service of the Illinois Central to become the first Chief Engineer of the Panama Canal. He found there an obsolete, inadequate plant which had to be scrapped and the work started anew from the very beginning. He had to gather together a complete organization in the face of great difficulties, and he laid foundations which those who followed him unhesitatingly acknowledge were largely responsible for the successful accomplishment of the project. Mr. Wallace returned from the Isthmus in 1906, and after a short period of rest was retained by the Chicago & Northwestern and conceived and designed the new passenger terminals for that railway in Chicago. Shortly thereafter he went to New York to become Chairman and later President of Westinghouse, Church, Kerr & Company, one of the large engineering organizations in the country.

For over ten years he directed the activities of that Company, which covered the entire field of engineering and extended all over the country.

Mr. Wallace's residence in New York brought him in direct contact with the great financial problems of the country, and his counsel was frequently sought on many matters outside the realm of engineering.

For the last five years Mr. Wallace has been a member of the Committee on Harbors and Shipping of the Chamber of Commerce, State of New York.

During the late war Mr. Wallace served as a member of the Transportation Committee of the National Petroleum Advisory Board.

In 1913 he was retained by the City of Chicago in an advisory capacity in connection with the west side Union Station. The work done in this connection laid the foundation for the establishment in 1914 of the Chicago Railway Terminal Commission, with Mr. Wallace as Chairman, in which capacity he continued until a few months ago.

During this time, in addition to working out the Union Station ordinance, he was successful in bringing to a final conclusion, through his great ability to harmonize conflicting human interests, the Illinois Central Lake Front ordinance, after thirty years of discussion of the Lake Front problem of Chicago.

It is worthy of notice that the final plans for the solution of the railway terminal problem at Chicago contemplate a consolidation of all passenger traffic in three stations, with all three of which Mr. Wallace was prominently identified.

At the time of his death, Mr. Wallace was in Washington attending hearings of the Senate Committee on Interstate Commerce in connection with the Board of Economics and Engineering recently formed by the National Association of railroad security holders.

Mr. Wallace had undertaken, as a member of this board, to present the economies possible to the unified or co-operative operation of railroad terminals. With his customary vision he saw the possibilities of great accomplishments through this board of economics and engineering. His last words before the Senate Committee voiced the earnest desire that he and the board with which he was associated might be helpful in the bringing together of apparently conflicting interest for the betterment of our transportation system. It would be difficult to imagine a more fitting closing chapter of a life so crowded with action—with achievement. Surely the soul of the man shines through these sentiments.

One who served under Mr. Wallace for many years says: "As I look back over his career I am impressed with the outstanding virtues for which the profession may be thankful—

1. His interest in and helpfulness to young engineers.
2. His wonderful initiative and energy.
3. His unblemished character in every phase of life."

If Mr. Wallace were asked how he would prefer to be remembered, he would say—"As a friend."

Not as the man who made possible perhaps the greatest piece of engineering the world has known—the building of the Panama Canal; not as the engineer whose vision was prophetic, and who builded not for the day but for generations to come; not for any of the splendid works which it was his privilege to perform—but rather as a friend.

Witness his advice to the 1916 Graduating Class of Monmouth College:

"My first advice to you would be to cultivate friends. Begin with your own family circle and let your friendships extend to include your neighbor, your city, your state, your country—and finally broaden it out to include and embrace humanity. Other things being equal, the measure of your success will depend upon your friendships."

And surely as he lived the above, he lived also this advice: "Cultivate a willingness to serve others, regardless of time, place or circumstances, not measuring your services pound for pound, as for compensation, but let the measure of what you give be overflowing."

The greatest writers of the world have given us volumes on the value of friendship—on its beauty, its ennobling qualities—John Findley Wallace gave his whole life in the practice of this virtue.

In 1898 Mr. Wallace became interested in the American Railway Engineering Association (at that time called "American Railway Engineering and Maintenance of Way Association") by reason of his appointment as Chairman of a committee, composed of representative railway officials, to draft a constitution for the proposed new organization. With characteristic energy, he carried out the assignment—with what thoroughness is attested by the fact that the organic law of the Association has remained unaltered, except in a few minor particulars, to the present day.

One of the principal factors in the remarkable record of the American Railway Engineering Association is the keynote on which Mr. Wallace placed especial emphasis in explaining the provisions of the Constitution to the preliminary organization meeting—"continuity of purpose." The Association has consistently adhered to that feature, the results of which are evident throughout the permanent printed record of the Association.

Another noteworthy feature is the unique method of working devised by the founders of the organization. The plan of appointing standing or practically permanent committees to study and report from year to year on various phases of subjects assigned has been one of the principal factors contributing to the achievements of the Association.

At the preliminary organization meeting held at Buffalo on March 30, 1899, Mr. Wallace was unanimously elected as the first President of the new Association, continuing in that capacity for two years—perhaps the most critical in its history. The new officers of the Association at that time were confronted with the necessity of "selling the proposition" to the railway world. Mr. Wallace's wide acquaintance, his high standing as an engineer and operating officer, proved of inestimable value to the Association at this period. From the beginning, the Association had the hearty approval and encouragement of the managements of railways, and has fully justified the confidence placed in it.

Mr. Wallace was an ideal presiding officer at meetings of the Association. From his wide experience, he drew freely for illustration of points under consideration. He had the happy faculty of making the discussions instructive as well as interesting, and he contributed markedly to the success of the deliberations.

Mr. Wallace's last appearance before the Association was at the annual dinner on March seventeenth of this year—1921. In his address, he reviewed briefly the steps leading up to the formation of the Association; explained for the benefit of the younger members some of the motives actuating the founders in building the frame-work or foundation of the substantial structure which has been reared in subsequent years, and gave some interesting reminiscences of the early years of the organization's existence.

The American Railway Engineering Association owes a great measure of its remarkable success to the genius of John Findley Wallace.

Mr. Wallace was married at Rock Island, Illinois, on September 11, 1871, to Miss Sarah E. Ulmer, who survives him. He left two children—Harold U. Wallace, a Civil Engineer, and Mrs. Birdena Wallace Le May.

Technical Societies to Which Mr. Wallace Belonged

Honorary Member and Past-President, Western Society of Engineers in Chicago, Illinois.

Honorary Member and Past-President, American Railway Engineering and Maintenance of Way Association.

Member of Institute of Consulting Engineers of America.

Member of Institution of Civil Engineers of Great Britain.

Member and Past-President, American Society of Civil Engineers.

During Mr. Wallace's administration as President in 1900, the American Society of Civil Engineers was the guest of the Institute of Civil Engineers of Great Britain and held its annual convention that year in the Society House of the Institute of Civil Engineers, at which convention Mr. Wallace delivered the regular annual address.

During this visit to London Mr. and Mrs. Wallace were personally presented to Queen Victoria at Windsor Castle.

Degrees

Mr. Wallace held the degree of Civil Engineer from the University of Wooster, Ohio—Degree of Doctor of Literary Laws from Monmouth College, Monmouth, Illinois—Degree of Doctor of Science from Armour Institute, Chicago, Illinois.

Clubs

Chicago—

Union League—Chicago Club—South Shore Country Club—Engineers Club—City Club—Association of Commerce—Press Club.

Washington—

Metropolitan—Cosmos.

New York—

Union League—Sleepy Hollow Country Club—Engineers Club—Engineers Country Club—Bankers Club of America—Chamber of Commerce—Automobile Club of America—National Arts Club—Railroad Club.

Prepared by George W. Kittredge, Chairman; L. A. Downs, L. C. Fritch, Howard G. Kelley, Hunter McDonald, A. W. Johnston, H. R. Stafford, Committee.

Colonel George Herbert Webb

George Herbert Webb

Director, American Railway Engineering Association

Died November 3, 1921

George Herbert Webb, the son of Colonel George Webb and Emma (Alder) Webb, was born in Dubuque, Iowa, on March 5, 1860. Both his father and mother came from Muncy, Lycoming County, Pennsylvania, where his grandfather had acquired a considerable estate in the early part of the last century. His father went west in 1850, but after the Civil War returned to the east and was prominently identified with the construction and operation of various railroads and with the steel industry. The family made their home in Williamsport, Pennsylvania, and in 1876 moved to Johnstown, Pennsylvania.

Mr. Webb was educated at the Pennsylvania Military College, Chester, Pennsylvania. He entered the sophomore class in engineering in September of 1877 and was graduated from this institution, then known as the Pennsylvania Military Academy, as a Civil Engineer (C. E.), June 10, 1880.

After graduation he entered railroad work as rodman with the Baltimore & Ohio Railroad. In 1881 he tested steel for the Brooklyn Bridge and in 1883 was appointed City Engineer of Johnstown, Pennsylvania. He was later Assistant Engineer of the Cambria Iron and Steel Company.

From the fall of 1885 to the spring of 1888 Mr. Webb was with the Chicago, Burlington & Quincy Railroad as transitman, Locating Engineer, and Division Engineer on construction, and in 1888 was Division Engineer in charge of the construction of portions of the Seattle, Lake Shore & Eastern (now a part of the Northern Pacific System).

In the spring of 1889 he went to Chile, South America, with the North and South American Construction Company. This company had a contract with the Chilean Government for building and equipping between six hundred and seven hundred miles of railroad, and Mr. Webb was in charge of the construction of one of the branch lines in the southern part of the Republic. The entire work was later stopped by the outbreak of the Balmaceda Revolution.

Upon leaving Chile he went to Peru, and in 1891 was appointed Division Engineer and Superintendent of construction of the Summit Division of the Central Railway of Peru, formerly the Aroya Road. The construction of this division was a notable piece of work. It crosses the main range of the Cordilleras de los Andes at an altitude of 15,657 feet above the sea level, with heavy grades and high curvature and many tunnels.

In 1893 Mr. Webb returned to the United States and engaged in private engineering practice until 1897, when he was appointed Chief Engineer of the Cincinnati, Georgetown & Portsmouth Railroad. This road was a small property in charge of Ralph Peters. While Mr. Webb's associations as Chief Engineer of this road were pleasant, he wished to study maintenance on larger roads, and at the end of two years resigned to enter the service of the Cleveland, Cincinnati, Chicago & St. Louis Railway.

During 1899 and 1900 he was supervisor of track on the latter road and on the Chicago & Alton Railroad, and in 1901 and 1902 Engineer in charge of construction of the Missouri Pacific shops at Baring Cross, Arkansas.

Mr. Webb entered the service of the Michigan Central Railroad in 1903 and had charge of relocating the main line betwen Kalamazoo and Lawton, Michigan, a work of considerable magnitude. He was successively promoted to the positions of Division Engineer and Assistant Chief Engineer, and in 1905 was appointed Chief Engineer. He occupied the latter position until his death with the exception of about two years, from 1917 to 1919, when he was in military service in France.

The Detroit passenger terminal of the Michigan Central is probably the most prominent monument to Mr. Webb's engineering ability. It may be included with such structures as the Grand Central and the Pennsylvania Terminals at New York, and the Kansas City Union Depot, as among the four or five most noted projects of this character which have been completed within the last decade.

Mr. Webb served in various important military positions in the American Army during the World War, attaining the rank of Colonel. He was awarded the Distinguished Service Medal,*

*General Orders, No. 59, War Department, Washington, 1919, p. 3.

also the French Ordre de l'Etoile Noire (Officer) by Presidential decree of September 24, 1919.

On July 6, 1917, he was appointed Lieutenant-Colonel in the Sixteenth (Railway) Engineers. The regiment landed in France on August 29th of the same year and took charge of the construction of the Advance Depot at Is-sur-Tille.

About April 1, 1818, Colonel Webb was placed in charge of a number of railway and camp projects in the vicinity of Nevers. This position soon developed into that of section engineer of the east half of the Intermediate Section. In this capacity Colonel Webb had charge of the American engineering projects in about one-seventh of the area of France, and extending from the city of Bourges to the Swiss and Italian borders. Among the projects carried on under his direction were the large hospital plants which were constructed at Mesves-Bulcy, Mars-sur-Allier, and Allerey, with a combined maximum capacity of 72,000 patients.

The Nevers Cutoff from an engineering point of view was the most difficult piece of railway construction in the A.E.F. It required a large yardage of embankment and the construction of a pile and steel truss bridge 2200 feet long over the Loire River. Other railway projects were the engine terminal at Marcy and the car repair shops at Nevers. Warehouses, camps, camp hospitals and laundries were constructed and re-organized at various centers, and at Vichy, Clermont-Ferrand, Chatel Guyon, Royat and Pougues-les-Eaux, groups of resort hotels were taken over and adapted to hospital purposes. At the center of Vichy alone over 75,000 patients were treated.

All this work was carried on subject to continuous wartime interference with the supply of men, materials, equipment and transportation. Colonel Webb's inspiring and compelling personality and genius for organization stirred the officers and men in the organizations under him to exceptional efficiency. By his resourcefulness, initiative and skill, he overcame all obstacles and completed these difficult projects with marked success.

On September 27, 1918, he was promoted to Colonel and in April, 1919, returned to this country and resumed his duties as Chief Engineer of the Michigan Central.

In the fall of 1920 Colonel Webb's health showed signs of failing and in the following spring an operation was performed, without, however, obtaining the hoped-for relief. He died on

November 3, 1921, at the home of his sister, Mrs. G. L. Osgood, Jr., near Boston.

Colonel Webb was a man of strong personality and sterling qualities. He was a thorough student and possessed keen insight, and his work showed in a high degree evidence of original, self-reliant thought and a keen sense of justice. His interesting experiences and unusual personal charm made him a delightful companion, and his death will be long felt by the many who enjoyed the privilege of knowing him.

In January, 1905, he was married to Jessie Lawrence, who lived a short time only after their marriage and died in May, 1907. They had many congenial tastes, and his home life afforded pleasant relief from the close application he was in the habit of giving to the duties of his profession. Her untimely death was much to be regretted.

The Board of Trustees of the Pennsylvania Military College on June 17, 1914, conferred upon Colonel Webb the honorary degree of Master of Civil Engineering, in recognition of his high professional attainments and his worth as a man and citizen.

At the time of his death he was a Director of the American Railway Engineering Association, having previously served the Association as chairman of the Committee on Rules and Organization. He was for many years a member of the American Society of Civil Engineers, as well as the first Commander of the Detroit Chapter of the Military Order of the World War, a member of the Sixteenth Engineers Post Veterans of Foreign Wars of the United States, and of the American Legion.

Prepared by J. F. Deimling, George H. Harris, E. R. Lewis, William H. Sellew.

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